RS Switch Router User Guide

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River STONE NETWORKS™

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This product complies with the following:

SAFETY

UL 1950; CSA C22.2, No. 950; 73/23/EEC; EN 60950; IEC 950

ELECTROMAGNETIC

FCC Part 15; CSA C108.8; 89/336/EEC; EN 55022; EN 61000-3-2

COMPATIBILITY (EMC)

EN 61000-3-3; EN 50082-1, AS/NZS 3548; VCCI V-3

REGULATORY COMPLIANCE STATEMENTS

Note Complies with Part 68, FCC rules.
FCC Registration Number 6TGUSA-46505-DE-N
Riverstone Networks, Inc.
Model WICT1-12
Made in U.S.A.

FCC COMPLIANCE STATEMENT

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment uses, generates, and can radiate radio frequency energy and if not installed in accordance with the operator's manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause interference in which case the user will be required to correct the interference at his own expense.

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Warning Changes or modifications made to this device that are not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

INDUSTRY CANADA COMPLIANCE STATEMENT

This digital apparatus does not exceed the Class A limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulations of the Canadian Department of Communications.

Le présent appareil numérique n'émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de la class A prescrites dans le Règlement sur le brouillage radioélectrique édicté par le ministère des Communications du Canada.

NOTICE: The Industry Canada label identifies certified equipment. This certification means that the equipment meets telecommunications network protective, operational, and safety requirements as prescribed in the appropriate Terminal Equipment Technical Requirements document(s). The department does not guarantee the equipment will operate to the user's satisfaction.

Before installing this equipment, users should ensure that it is permissible to be connected to the facilities of the local telecommunications company. The equipment must also be installed using an acceptable method of connection. The customer should be aware that compliance with the above conditions may not prevent degradation of service in some situations.

Repairs to certified equipment should be coordinated by a representative designated by the supplier. Any repairs or alterations made by the user to this equipment, or equipment malfunctions, may give the telecommunications company cause to request the user to disconnect the equipment.

Users should ensure for their own protection that the electrical ground connections of the power utility, telephone lines, and internal metallic water pipe system, if present, are connected together. This precaution may be particularly important in rural areas.

CAUTION: Users should not attempt to make such connections themselves, but should contact the appropriate electric inspection authority, or electrician, as appropriate.

NOTICE: The Ringer Equivalence Number (REN) assigned to each terminal device provides an indication of the maximum number of terminals allowed to be connected to a telephone interface. The termination on an interface may consist of any combination of devices subject only to the requirement that the sum of the Ringer Equivalence Numbers of all the devices does not exceed 5.

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VCCI COMPLIANCE STATEMENT

This is a Class A product based on the standard of the Voluntary Control Council for Interference by Information Technology Equipment (VCCI). If this equipment is used in a domestic environment, radio disturbance may arise. When such trouble occurs, the user may be required to take corrective actions.

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SAFETY INFORMATION: CLASS 1 LASER TRANSCEIVERS

This product may use Class 1 laser transceivers. Read the following safety information before installing or operating this product.

The Class 1 laser transceivers use an optical feedback loop to maintain Class 1 operation limits. This control loop eliminates the need for maintenance checks or adjustments. The output is factory set and does not allow any user adjustment. Class 1 laser transceivers comply with the following safety standards:

- 21 CFR 1040.10 and 1040.11, U.S. Department of Health and Human Services (FDA)
- IEC Publication 825 (International Electrotechnical Commission)
- CENELEC EN 60825 (European Committee for Electrotechnical Standardization)

When operating within their performance limitations, laser transceiver output meets the Class 1 accessible emission limit of all three standards. Class 1 levels of laser radiation are not considered hazardous.

LASER RADIATION AND CONNECTORS

When the connector is in place, all laser radiation remains within the fiber. The maximum amount of radiant power exiting the fiber (under normal conditions) is –12.6 dBm or 55 x 10^{-6} watts.

Removing the optical connector from the transceiver allows laser radiation to emit directly from the optical port. The maximum radiance from the optical port (under worst case conditions) is 0.8 W cm^{-2} or 8 x 10^{3} W m^{2} sr–1.

Do not use optical instruments to view the laser output. The use of optical instruments to view laser output increases eye hazard. When viewing the output optical port, power must be removed from the network adapter.

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SAFETY INFORMATION: WICT1-12 T1 CARD

Warning To reduce the risk of fire, use only No. 26 AWG or larger telecommunication line cord.

CONSUMER INFORMATION AND FCC REQUIREMENTS

1. This equipment complies with Part 68 of the FCC rules, FCC Registration Number 6TGUSA-46505-DE-N Riverstone Networks Inc. Model WICT1-12 Made in the USA. On the DS1/E1 WAN Module of this equipment is a label that contains, among other information, the FCC registration number and Ringer Equivalence Number (REN) for this equipment. If requested, provide this information to your telephone company.
2. The REN is useful to determine the quantity of devices you may connect to your telephone and still have all those devices ring when your number is called. In most, but not all areas, the sum of the REN's of all devices should not exceed five (5.0). To be certain of the number of devices you may connect to your line, as determined by the REN, you should call your local telephone company to determine the maximum REN for your calling area.
3. If your DS1/E1 WAN Module causes harm to the telephone network, the Telephone Company may discontinue your service temporarily. If possible, they will notify you in advance. But if advance notice isn't practical, you will be notified as soon as possible. You will be advised of your right to file a complaint with the FCC.
4. Your telephone company may make changes in its facilities, equipment, operations, or procedures that could affect the proper operation of your equipment. If they do, you will be given advance notice so as to give you an opportunity to maintain uninterrupted service.
5. If you experience trouble with this equipment DS1/E1 WAN Module, please contact Riverstone Networks Inc., 5200 Great America Parkway, Santa Clara, CA 95054, 408 878-6500, for repair/warranty information. The Telephone Company may ask you to disconnect this equipment from the network until the problem has been corrected or you are sure that the equipment is not malfunctioning.
6. There are no repairs that can be made by the customer to the DS1/E1 WAN Module.
7. This equipment may not be used on coin service provided by the Telephone Company. Connection to party lines is subject to state tariffs. (Contact your state public utility commission or corporation commission for information).

EQUIPMENT ATTACHMENT LIMITATIONS NOTICE

The Industry Canada label identifies certified equipment. This certification means that the equipment meets the telecommunications network protective, operational and safety requirements as prescribed in the appropriate Terminal Equipment Technical Requirements document(s). The Department does not guarantee the equipment will operate to the user's satisfaction.

Before installing this equipment, users should ensure that it is permissible to be connected to the facilities of the local telecommunications company. The equipment must also be installed using an acceptable method of connection. The customer should be aware that the compliance with the above conditions may not prevent degradation of service in some situations.

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Caution: Users should not attempt to make connections themselves, but should contact the appropriate electric inspection authority, or electrician, as appropriate.

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Application of Council Directive(s)	89/336/EEC 73/23/EEC
Manufacturer's Name	Riverstone Networks, Inc.
Manufacturer's Address	5200 Great America Parkway Santa Clara, CA 95054
Conformance to Directive(s)/Product Standards	EC Directive 89/336/EEC EC Directive 73/23/EEC EN 55022 EN 50082-1 EN 60950
Equipment Type/Environment	Networking equipment for use in a commercial or light-industrial environment

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1 INTRODUCTION

This manual provides information for configuring the Riverstone RS Switch Router software. It details the procedures and provides configuration examples. If you have not yet installed the RS, use the instructions in the *Riverstone RS Switch Router Getting Started Guide* to install the chassis and perform basic setup tasks, then return to this manual for more detailed configuration information.

1.1 RELATED DOCUMENTATION

The Riverstone RS Switch Router documentation set includes the following items. Refer to these other documents to learn more about your product.

For Information About	See
Installing and setting up the RS	*Riverstone RS Switch Router Getting Started Guide*
Syntax for CLI commands	*Riverstone RS Switch Router Command Line Interface Reference Manual*

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1.2 DOCUMENT CONVENTIONS

Commands shown in this manual use the following conventions:

Convention	Description
boldface	Indicates commands and keywords that you enter as shown.
<*italics*>	Indicates arguments for which you supply values.
[**x**] or [<*italics*>] or [**x** <*italics*>]	Keywords and arguments within a set of square brackets are optional.
x|y|z|<*italics*> or [**x|y|z|**<*italics*>]	Keywords or arguments separated by vertical bars indicate a choice. Select one keyword or argument.
{**x|y|z|**<*italics*>}	Braces group required choices. Select one keyword or argument.

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2 MAINTAINING CONFIGURATION FILES

This chapter provides information about configuration files in the Riverstone RS Switch Router (RS). It explains the different types of configuration files and the different procedures involved in changing, displaying, saving, and backing up the files.

2.1 CONFIGURATION FILES

The *Riverstone RS Switch Router Getting Started Guide* introduced the following configuration files used by the RS:

- **Startup** – The configuration file that the RS uses to configure itself when the system is powered on. The Startup configuration remains even when the system is rebooted.
- **Active** – The commands from the Startup configuration file and any configuration commands that you have made active from the scratchpad. The active configuration remains in effect until you power down or reboot the system.

Caution The active configuration remains in effect only during the current power cycle. If you power off or reboot the RS without saving the active configuration changes to the Startup configuration file, the changes are lost.

- **Scratchpad** – The configuration commands you have entered during a CLI session. These commands are temporary and do not become active until you explicitly make them part of the active configuration.

Because some commands depend on other commands for successful execution, the RS scratchpad simplifies system configuration by allowing you to enter configuration commands in any order, even when dependencies exist. When you activate the commands in the scratchpad, the RS sorts out the dependencies and executes the command in the proper sequence.

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The following figure illustrates the configuration files and the commands you can use to save your configuration:

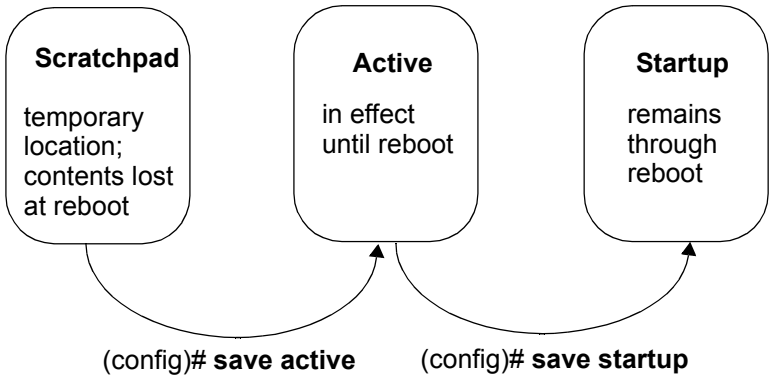

Figure 2-1 Commands to save configurations

2.1.1 Changing Configuration Information

The RS provides many commands for changing configuration information.

Use the **negate** command on a specific line of the active configuration to "disable" a feature or function which has been enabled.

Table 2-1 Commands to change configuration information

Task	Command
Enable Mode:	
Copy between scratchpad, active configuration, startup configuration, TFTP server, RCP server, or URL.	**copy** <*source*> **to** <*destination*>
Configure Mode:	
Erase commands in scratchpad.	**erase scratchpad**
Erase startup configuration.	**erase startup**
Negate one or more commands by line numbers.	**negate** <*line number*>
Negate commands that match a specified command string.	**no** <*string*>
Save scratchpad to active configuration.	**save active**
Save active configuration to startup.	**save startup**

2.1.2 Displaying Configuration Information

The following table lists the commands that are useful for displaying the RS's configuration information.

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Table 2-2 Commands to display configuration information

Task	Command
Enable Mode:	
Show active configuration of the system.	**system show active**
Show the non-activated configuration changes in the scratchpad.	**system show scratchpad**
Show the startup configuration for the next reboot.	**system show startup**
Configure Mode:	
Show active configuration of the system.	**show active**
Show the non-activated configuration changes in the scratchpad.	**show scratchpad**
Show the startup configuration for the next reboot.	**show startup**
Show the running system configuration, followed by the non-activated changes in the scratchpad.	**show**
Compare activated commands with the startup configuration file.	**diff** <*filename*> | **startup**

The **show** and **system show** commands display the commands in the order they were executed. You can change this sequence to alphabetical order by using the **system set show-config** command.

2.1.3 Activating the Configuration Commands in the Scratchpad

The configuration commands you have entered using procedures in this chapter are in the Scratchpad but have not yet been activated. Use the following procedure to activate the configuration commands in the scratchpad.

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Ensure that you are in Configure mode by entering the **configure** command in the CLI.
3. Enter the following command:

```
save active
```

The CLI displays the following message:

```
Do you want to make the changes Active? [y]
```

4. Type **y** to activate the changes.

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Note If you exit the Configure mode (by entering the **exit** command or pressing **Ctrl+Z**), the CLI will ask you whether you want to make the changes in the scratchpad active.

2.1.4 Saving the Active Configuration to the Startup Configuration File

After you save the configuration commands in the scratchpad, the control module executes the commands and makes the corresponding configuration changes to the RS. However, if you power off or reboot the RS, the new changes are lost. Use the following procedure to save the changes into the Startup configuration file so that the RS reinstates the changes when you reboot the software.

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Enter the following command to copy the configuration changes in the Active configuration to the Startup configuration:

```
copy active to startup
```

3. When the CLI displays the following message, enter **yes** to save the changes.

```
Are you sure you want to overwrite the Startup configuration? [n]
```

Note You also can save active changes to the Startup configuration file from within Configure mode by entering the **save startup** command.

The new configuration changes are added to the Startup configuration file stored in the control module's boot flash.

2.1.5 Viewing the Current Configuration

To view the current configuration:

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Enter the following command to display the status of each command line:

```
system show active-config
```

The CLI displays the active configuration file with the following possible annotations:

- Commands without errors are displayed without any annotation.
- Commands with errors are annotated with an "E."

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- If a particular command has been applied such that it can be expanded on additional interfaces/modules, it is annotated with a "P". For example, if you enable STP on all ports in the current system, but the RS contains only one module, then the command to enable STP will be applied at a later date when more modules have been added.

  A command like **`stp enable et.*.*`** would be displayed as follows:

```
P: stp enable et.*.*
```

  This indicates that it is only partially applied. If you add more modules to the RS at a later date and then update the configuration file to encompass all of the available modules in the RS, then the **`P:`** portion of the above command line would disappear when this configuration file is displayed.

  If a command that was originally configured to encompass all of the available modules on the RS becomes only partially active (after a hotswap or some such chassis reconfiguration), then the status of that command line automatically changes to indicate a partial completion status, complete with **`P:`**.

Note Commands with no annotation or annotated with **`P:`** are not in error.

2.1.6 Backing Up and Restoring Configuration Files

When you save the startup configuration file, the RS stores it in three places: in the bootflash and the PC card of the primary control module, and if there is a redundant control module, in its PC flash card as well. It is recommended that you store a backup of the startup configuration file in the boot flash of the control module and on a central server. Use the **`copy`** command in Enable mode to store a backup copy of the startup configuration file in the control module, backup control module (if applicable), and on a server:

```
copy startup to backup-CM|tftp-server|rcpserver|<filename>|<url>
```

For example, to make a backup in the control module, specify the following command in Enable mode:

```
copy startup to startup.bak
```

If the startup file becomes corrupted, the RS uses its default configuration. You can then use the copy command to copy the backup file to the startup, as shown in the following example:

```
copy startup.bak to startup
```

Use the **`file`** commands in Enable mode to display, rename, and delete the configuration files stored on the primary control module:

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Table 2-3 File commands

Display a directory of the files in the bootflash or in the PC card.	**file dir** <*device*>
Display the contents of a file in the bootflash.	**file type [**<*device*>**:]**<*filename*>
Delete the specified file.	**file delete [**<*device*>**:]**<*filename*>
Copy a file to a different device and/or filename.	**file copy [**<*device1*>**:]**<*source-filename*> **[**<*device2*>**:]**<*dest-filename*>
Erase all files on the specified device.	**file reformat** <*device-name*>
Rename a file.	**file rename [**<*device*>**:]**<*source-filename*> <*dest-filename*>

Note The **file** commands apply to devices and files in the primary Control Module. You cannot display, delete, or rename files in the backup Control Module. You can, however, use the CLI **copy** command to copy configuration files from the primary Control Module to the backup Control Module.

2.2 BACKING UP AND RESTORING SYSTEM IMAGE FILES

When you boot up the system, the RS boots up the system image off the PC flash card. The PC flash card contains the run-time image (the PC flash may store up to two images, depending on its capacity) and the startup configuration file.

It is recommended that a backup of the system image be stored on a central server in the unlikely event that the system image becomes corrupted or deleted from the PC flash card. Use the **system set bootprom** command in Configure mode to set parameters for the RS to boot the system image remotely over a network.

```
system set bootprom netaddr <IPaddr> netmask <IP netmask> tftp-server
<IPaddr> tftp-gateway <IPaddr>
```


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If the RS boots up from the PC flash card and cannot find a valid image, it goes into boot prom mode. If the en0 interface is configured and connected to a network, you can download an image to the PC flash by using the **system image add** command in Enable mode. If the en0 interface has not been configured, then you will need to configure it by specifying the following: IP address and netmask of the RS, IP address of the TFTP server, and IP address of the default gateway. Use the following commands in boot mode:

```
set net-addr <IP-address>
set netmask <netmask>
set boot-addr <tftp-server address>
set gateway <IP-address of default gateway>
```

Then, boot the RS by specifying the following command:

```
boot <directory/filename of the image file to boot from>
```

Alternatively, you can use the **set boot source** command:

```
set boot source <filename>
```

Once the RS has booted from the TFTP server image through en0, you can add the new image to the PC card by using the **system image add** command.

Additionally, you can use the following commands to display, add, and delete system images:

Table 2-4 System image commands

Copy a system software image to the RS.	**system image add** *<IPaddr-or-hostname>* *<filename>***[primary-cm|backup-cm] [slot0|slot1]**
Select a system software image for booting.	**system image choose** *<filename>***|none [primary-cm|backup-cm] [slot0|slot1]**
Copy a system software image from one PC card to another.	**system image copy slot0|slot1** *<filename>* **slot0|slot1 [***<filename>***]**
List system software images on the PC flash card.	**system image list primary-cm|backup-cm|all**
Delete a system software image file from the PC flash card.	**system image delete** *<filename>* **primary-cm|backup-cm slot0|slot**

2.3 CONFIGURING SYSTEM SETTINGS

In addition to the initial settings described in the *Getting Started Guide*, there are additional system features which you can set on the RS.

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2.3.1 Setting Daylight Saving Time

Daylight saving time (DST) on the RS can be set three different ways:

- According to specific days. For example, from the first Sunday of April to the last Saturday of October.
- According to specific dates. For example, from April 1st to October 31st.
- By setting the RS's time forward by an hour.

When you specify the **system set dst-changing** command or the **system set dst-fixed** command in the active configuration file, the RS automatically updates the time based on the parameters you entered. When a time change happens, the RS automatically sends an informational message about the time change. Enter one of the following commands in Configure mode to set DST according to specific days or dates:

Set DST according to specific days.	**system set dst-changing s_wk** <*value*> **s_dow** <*value*> **s_mo** <*value*> **s_hr** <*value*> **s_min** <*value*> **e_wk** <*value*> **e_dow** <*value*> **e_mo** <*value*> **e_hr** <*value*> **e_min** <*value*>
Set DST according to specific dates.	**system set dst-fixed s_mo** <*value*> **s_day** <*value*> **s-hr** <*value*> **s_min** <*value*> **e_mo** <*value*> **e_day** <*value*> **e_hr** <*value*> **e_min** <*value*>

When you set DST by setting the time forward by an hour, saving it to the active configuration file automatically activates the command, causing the time to immediately change forward one hour. Use the **negate** command to set the time back. Enter the following command in Configure mode to move the time forward by an hour:

Set the time forward by one hour.	**system set dst-manual**

2.3.2 Configuring a Log-in Banner

Configure the RS to display a banner when it is booted up. You can specify a text string or the name of a file on a TFTP server.

Display a log-in banner.	**system set login banner** [<*string*> | **none|file-name** <*name*>

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3 CLI AND RS BASICS

This chapter provides basic information about the Command Line Interface (CLI) and the RS. It includes:

- How to start the CLI
- Information about CLI command modes
- Information about CLI commands
- Information about line editing commands
- How to get online help
- How to set CLI parameters
- Information about naming RS ports
- How to set up a basic configuration for the CLI and the RS

3.1 STARTING THE CLI

To start the CLI boot up the RS. After the RS boots up, the CLI appears in the Telnet or console window. The following message displays:

```
Press RETURN to activate console . . .
```

Press the Return key. The following message displays:

```
%SYS-W-NOPASSWD, no password for login, use 'system set password' in Config mode
rs>
```

The first line in the above example means that a password for login has not been set up yet. Information about setting the login password is found in the *Riverstone RS Switch Router Getting Started Guide.*

`rs>` is the initial CLI command prompt in the user mode. Begin using the CLI from here. From this prompt all command modes in the CLI can be reached. There is also a set of facilities associated with this mode.

See the following section for a discussion about CLI command modes.

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3.2 UNDERSTANDING CLI COMMAND MODES

The CLI has four separate command modes. Each command mode controls a group of related commands. This section explains the primary uses for each command mode.

3.2.1 User Mode

The initial mode on the RS after booting up is the user mode. The user mode commands are a subset of the enable mode commands. In general, the user commands display basic information and contain basic utilities such as PING. This mode also contains the command to enter the enable mode.

The user mode command prompt consists of the RS name followed by the angle bracket (>), as shown in the following:

```
rs>
```

3.2.2 Enable Mode

The enable mode provides more commands than the user mode. Commands within the enable mode include:

- Router configuration
- Access Control Lists
- SNMP statistics
- Telnet
- TACACS and TACACS-Plus
- DHCP
- Help
- Configure (to enter the configure mode)

The commands in this mode are *persistent* for the session. That is, they affect the current session only. To enter the enable mode from the user mode, type **`enable`** at the user command prompt. This mode also contains the command to enter the configure mode.

The enable mode command prompt consists of the RS name followed by the pound sign(#):

```
rs#
```

To exit the enable mode and return to the user mode, either type **`exit`** and press the Return key, or press Ctrl+Z.

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3.2.3 Configure Mode

The configure mode provides the capability of configuring and displaying all features and functions on the RS. The commands in this mode are *persistent* for the current session and future sessions. That is, they can be saved not only in onboard memory but also the startup configuration file. The startup configuration file is the file that the RS boots from. For detailed information about the startup configuration file, see Chapter 2, *"Maintaining Configuration Files."* To enter the configure mode, type **`config`** at the enable mode command prompt.

The configure mode command prompt consists of the RS name followed by `(config)` and a pound sign (#):

```
rs(config)#
```

To exit the configure mode and return to enable mode, either type **`exit`** and press the Return key, or press Ctrl+Z.

3.2.4 BootPROM Mode

The BootPROM mode is used to view and edit the current BootPROM configuration file. While the RS is booting up, press the Esc key. Then at the command prompt type **`set`**. The BootPROM configuration file displays. Changes can be made from this prompt.

The BootPROM mode command prompt consists of the word `rs-boot` followed by a > character.

```
rs-boot>
```

To exit the BootPROM mode and return to the CLI, reboot the RS.

3.3 UNDERSTANDING CLI COMMANDS

CLI commands are grouped by facilities. For example, the set of commands used to configure and display IP routing table information all start with **`ip`**, signifying the **`ip`** facility. Within the set of **`ip`** commands are commands such as:

- **`set`** – Used to configure parameters.
- **`show`** – Used to display.
- **`start`** – Used to start protocols operating.
- **`stop`** – Used to stop protocols from operating.
- **`configure`** – Used to configure parameters.

The complete set of commands for each facility is described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

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Note Some CLI modes may have the same commands. For example, the configure mode has **`port`** commands. These **`port`** commands are for making configuration changes to ports on the RS. The enable mode also has **`port`** commands. The **`port`** commands found in this mode display port statistics. They are not designed to change the way a port functions like the **`port`** commands in the configure mode do.

3.4 USING LINE EDITING COMMANDS

The CLI provides line editing capabilities that are similar to Emacs, a Unix text editor. Use line editing keystrokes to move forward or backward on a line, delete or transpose characters, or delete portions of a line. The line editing commands in the CLI are detailed in the following table.

Table 3-1 CLI line editing commands

Command	Resulting Action
Ctrl+a	Move to the beginning of line.
Ctrl+b	Move back one character.
Ctrl+c	Abort the current line.
Ctrl+d	Delete the character under the cursor.
Ctrl+e	Move to the end of the line.
Ctrl+f	Move forward one character.
Ctrl+g	Abort the current line.
Ctrl+h	Delete the character to the left of the cursor.
Ctrl+i	Insert one space (tab substitution).
Ctrl+j	Carriage return (executes a command).
Ctrl+k	Kill the line from the cursor to the end of the line.
Ctrl+l	Refresh the current line.
Ctrl+m	Carriage return (executes command).
Ctrl+n	Next command from the history buffer.
Ctrl+o	No action.
Ctrl+p	Previous command from the history buffer.
Ctrl+q	No action.
Ctrl+r	Refresh the current line.
Ctrl+s	No action.

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Table 3-1 CLI line editing commands (Continued)

Command	Resulting Action
Ctrl+t	Transpose the character under the cursor with the character to the left of the cursor.
Ctrl-u	Delete the line from the beginning of the line to the cursor.
Ctrl-v	No action.
Ctrl+w	No action.
Ctrl+x	Move forward one word.
Ctrl-y	Paste back what was deleted by the previous Ctrl+k or Ctrl+w command. The text is pasted back at the cursor location.
Ctrl+z	If in a facility, exit back to the next top level. If in the enable mode, exit back to the user mode. If in the configure mode, exit back to the enable mode.
ESC b	Move backward one word.
ESC d	Kill the word from the cursor's current location to the first white space.
ESC f	Move forward one word.
ESC BackSpace	Delete backwards from cursor to the previous space (essentially a delete-word-backward command)
Space Bar	Completes the command keyword. If the word is not a keyword, a space character is inserted.
! *	Show all commands currently stored in the history buffer.
! #	Recall a specific history command. # is the number of the history command to be recalled.
"<string>"	Opaque strings may be specified using double quotes. This prevents interpretation of otherwise special CLI characters.

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3.5 GETTING HELP WITH CLI COMMANDS

Interactive help is available in the CLI. Invoke help by entering a question mark (**?**) character at any command prompt, or after a keyword in any mode. Then press Enter. A set of facility names will display. These are the facilities and commands that can be used in that particular mode. Following is an example of typing **?** at the enable prompt:

```
rs> ?
 aging                    - Show Aging information
 cli                      - Modify the command line interface behavior
 dvmrp                    - Show DVMRP related parameters
 enable                   - Enable privileged user mode
 exit                     - Exit current mode
 file                     - File manipulation commands
 help                     - Describe online help facility
 igmp                     - Show IGMP related parameters
 ip-redundancy            - Show IP Redundancy information (VRRP)
 ipx                      - Show IPX related parameters
 l2-tables                - Show L2 Tables information
 logout                   - Log off the system
 multicast                - Show Multicast related parameters
 ping                     - Ping utility
 pvst                     - Show Per Vlan Spanning Tree Protocol (PVST)
                            parameters
 sfs                      - Show SecureFast Switching (SFS) parameters
 statistics               - Show or clear router statistics
 stp                      - Show Spanning Tree Protocol (STP) parameters
 telnet                   - Telnet utility
 traceroute               - Traceroute utility
 vlan                     - Show VLAN related parameters
```

Invoking Help While Entering a Command

Type the **?** character after entering a command to see a list of the parameters or options to choose to use with that command. Once the help information is displayed, the command is displayed as before but without the **?** character. Following is an example of invoking help while entering a command:

```
rs(config)# load-balance create ?
 group-name               - Name of this Load Balanced group of servers
 vip-range-name           - Name of this Virtual IP range
rs(config)# load-balance create
```


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Invoking Help Option by Option

Alternatively, a command can be entered option by option. First enter the facility name. Then press Enter to execute. For example, enter **ip** at the configure prompt. The prompt changes to indicate that the context of the current CLI command is changed to **ip**. Now type a **?** character, then press Enter. The options valid for **ip** are displayed. Choose an option and type it in. For example, type **add**. Press enter to execute. Type a **?** character, then press Enter. More options are displayed. Following is an example:

```
rs1(config)# ip
rs1(config)(ip)# ?
 add                      - Add a static route
 apply                    - apply profile to slot
 bgp-accounting           - Start BGP Accounting
 community-list           - Add a community list entry
 define                   - Define a custom forwarding profile
 disable                  - Disable certain IP function
 dos                     - Configure specific denial of service features
 enable                   - Enable certain IP function
 helper-address           - Specify IP helper address for an interface
 l3-deep-hashing          - Enable or Disable deep hashing for module
 l3-hash                  - Change IP hash variant for module
 set                      - Set ip stack properties
 Ctrl-z                   - Exits to previous level
 top                      - Exits to the top level
rs1(config)(ip)# add
rs1(config)(ip-add)# ?
 route                    - route parameters
 Ctrl-z                   - Exits to previous level
 top                     - Exits to the top level
```

3.6 SETTING CLI PARAMETERS

The RS provides commands for setting the following basic system parameters:

- System time and date
- System name
- System location
- Contact name (the person to contact regarding this RS)
- IP address for the management port

For an example of these commands see Section 3.8, *"CLI and RS Configuration Example."* For more information about these commands see the *Riverstone RS Switch Router Getting Started Guide*.

Additionally, the RS provides commands for controlling the behavior and display of the CLI:

- Command completion
- Command history
- Terminal display

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Command Completion

The **cli set command completion** command controls the behavior of the CLI as commands are entered. When command completion is enabled, the CLI automatically completes a command keyword that is partially entered. To execute, type enough characters of a command keyword to uniquely identify it and the press the Space Bar. The CLI completes the command word and moves to the next command entry point.

In the configure mode, this command enables or disables command completion for the entire system. In the enable mode, the command only affects the current session.

Command History

Command history is a buffer that holds a list of commands that were executed during a CLI session. The **cli set history** command specifies the number of commands that will be stored in the command history buffer. Commands stored in the buffer can be recalled without typing the complete command again. When the ↑ key is pressed, the CLI displays the commands that were entered. Additionally, all the commands that were executed during a CLI session can be displayed using the **cli show history** command.

Terminal Display

The CLI also provides commands for setting the terminal display. Row (horizontal) and column (vertical) of the display can be changed using the **cli set terminal** command.

3.7 NAMING RS PORTS

Much of the work done in the CLI is configuring ports on an RS. The name of a port is required to configure the port. The CLI provides commands to name ports. The figure below shows two 1000 Base-SX ports on a line card.

Each port on the RS is named in the following manner:

- For channelized ports:

  <type>.<slot-number>.<port-number>[:*<channel-number>*][.*<vc>*]
- For other ports, including unchannelized T1/E1:

  <type>.<slot-number>.<port-number>[.*<vc>*]

The various parts of the port specification are described in the following sections.

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3.7.1 Port Type

Table 3-2 describes the port type and associated line cards.

Table 3-2 Port type designations

Type	Line Card
at	Asynchronous Transfer Mode (ATM)
cm	Cable Modem Termination System (CMTS)
e1	Channelized E1
e3	Clear Channel E3
et	10 Base-*X*/100 Base-*X* Ethernet
gi	1000 Base-*X* Gigabit Ethernet
hs	Dual HSSI WAN
se	Serial WAN
so	Packet-over-SONET (POS)
t1	Channelized T1
t3	Channelized T3 or Clear Channel T3

3.7.2 Slot Number

Slot number is determined by the RS model and the physical slot in which the line card is installed. On the RS 1000 and RS 3000 the slot number is printed on the outside side of each slot. On the RS 8000, RS 8600, RS 32000, and RS 38000 the slot number is printed on the top of the front fan cover.

3.7.3 Port Number

Port number is the number assigned to the physical connector on the line card. The range and assignment of port numbers varies by chassis and the type of line card. Assignment of port numbers by line card is shown in Table 3-3:

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Table 3-3 Port numbers for line cards

Line Card	Port Numbering (Left to Right)								
10/100 Base TX	1	2	3	4	5	6	7	8	
100 Base FX	3 1	4 2		7 5	8 6				
1000 Base SX/LX	1	2							
1000 Base LLX	1								
Quad Serial WAN	1,2	3,4							
HSSI WAN	1	2							
SONET (OC-3c)	1	2	3	4					
SONET (OC-12c)	1	2							
ATM (OC-3)	1	2							
16-slot 10/100 Base TX	2 1	4 3	6 5	8 7		10 9	12 11	14 13	16 15
Channelized T1 WIC	1	2							
Channelized E1 WIC	1	2							
Channelized T3 on the RS 8000 and the RS 8600	1	2							
Channelized T3 on the RS 32000 and the RS 38000	1	2	3	4					
Multi-rate WAN Module with a Channelized T1 or Channelized E1 WIC in each slot	1†	2	3	4					
Multi-rate WAN Module with a Clear Channel T3 or Clear Channel E3 WIC in each slot	1†		3					1 3	
DOCSIS/EuroDOCSIS CMTS	1 US*	2 US	3 US	4 US	1 DS-IF**				

† The port numbering, when using a Clear Channel T3 or E3 WIC with a Channelized T1 or E1 WIC depends on the slot in which the WIC is placed. For example, if a Clear Channel WIC is in the first slot, and a Channelized WIC in the second, then the port numbers will be 1, 3, and 4. If the position of the WICs are reversed, then the numbering will be 1, 2, and 3.

* Upstream

** Downstream-Intermediate Frequency

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For a port numbering example, the port name et.2.8 refers to a port on the Ethernet line card that is located in slot 2, connector 8, while the port name gi.3.2 refers to a port on the Gigabit Ethernet line card located in slot 3, connector 2.

There are a few shortcut notations to reference a range of port numbers. For example:

- et.(1-3).(1-8) references all the following ports: et.1.1 through et.1.8, et.2.1 through et.2.8, and et.3.1 through et.3.8.
- et.(1,3).(1-8) references the following ports: et.1.1 through et.1.8, and et.3.1 through et.3.8
- et.(1-3).(1,8) references the following ports: et.1.1, et.1.8, et.2.1, et.2.8, et.3.1, et.3.8

3.7.4 Channel Number

Channel number is the number assigned to the timeslots or T1 lines in a connector, available only for Channelized T1, E1, and T3 interfaces. For Channelized T1 and E1, and fractional T1 and E1 interfaces, it is a timeslot. For Channelized T3 interfaces, it is a T1 line.

Specify a single channel number, a comma-separated list of channel numbers, or a range of channel numbers. For a channel range, specify a *start-channel* and an *end-channel*. The *end-channel* value must be greater than the *start-channel* value.

For other port types, including unchannelized T1 and E1, omit <*channel-number*> and the preceding colon (:). The <*vc*> parameter is still permitted. See Table 3-4.

Table 3-4 Channelized T1, E1 and T3 timeslot ranges

Range	Channel
1 to 24	Channelized T1
1 to 31	Channelized E1
1 to 28	Channelized T3

The following examples show the different channel specifications for T1:

t1.3.2:5-8
t1.3.1:(1-4,6,7)

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3.7.5 VC

This is the Virtual Channel (VC) number for a Frame Relay interface.

3.7.6 Port Name Example

Following is a 1000 Base-SX line card with two gigabit ports:

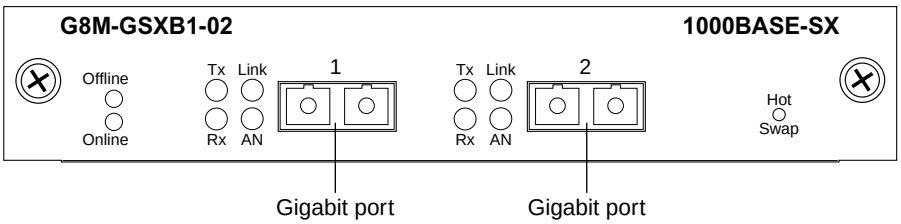

Figure 3-1 1000-Base-SX line card

This line card resides in slot 7 of an RS 8000. The names of the two ports from left to right are gi.7.1 and gi.7.2.

3.8 CLI AND RS CONFIGURATION EXAMPLE

The configuration will demonstrate how to set:

- The system time and date
- The daylight saving time
- The system name
- The system location
- The contact name (the person to contact regarding this RS)
- The IP address for the management port
- The terminal display (horizontal and vertical)
- The history buffer
- A login banner

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Here are the commands:

1. *Set the date and time.*

```
rs# system set date year 2001 month april day 30 hour 1 minute 0 second 0
```

2. *Set the monitor's horizontal and vertical.*

```
rs# cli set terminal columns 36 rows 60
```

3. *Set the history buffer size.*

```
rs# cli set history size 100
```

4. *Change modes.*

```
rs# configure
```

5. *Enable the daylight savings function.*

```
rs# configure system set dst-changing s-wk 5 s-dow 1 s-mo 3 e-wk 1 e-dow 7 e-mo 10
e-hr 2
```

6. *Name the* RS.

```
rs(config)# system set name "mktg-rs"
```

7. *Set the location.*

```
rs(config)# system set location "Santa Cruz, CA"
```

8. *Identify the contact name.*

```
rs(config)# system set contact "Jim Cale"
```

9. *Configure en0.*

```
rs(config)# interface add ip en0 address-netmask 160.150.140.20/16
```

10. *Create a login banner.*

```
rs(config)# system set login banner file-name loginbanner1
```


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4 HOT SWAPPING LINE CARDS AND CONTROL MODULES

4.1 HOT SWAPPING OVERVIEW

Hot swapping is the ability to replace a line card, Control Module, or GBIC (in the RS 32000 and RS 38000 only) while the RS is operating. Hot swapping allows you to remove or install line cards without switching off or rebooting the RS. Swapped-in line cards are recognized by the RS and begin functioning immediately after they are installed.

On the RS 8000 and RS 8600, you can hot swap line cards and secondary control modules. On the RS 8600, you can also hot swap the secondary switching fabric module. On the RS 32000 and RS 38000, you can hot swap the GBICs, in addition to the line cards and secondary control modules.

Caution Take appropriate care when removing line cards from the RS. They may be hot to the touch.

Warning The RS and its components are sensitive to static discharge. Use an antistatic wrist strap and observe all static precautions when hot swapping the RS's components.

This chapter provides instructions for the following tasks:

- Hot swapping line cards
- Hot swapping secondary Control Modules
- Hot swapping the secondary Switching Fabric Module (RS 8600 only)
- Hot swapping the GBIC (RS 32000 and RS 38000 only)

4.2 HOT SWAPPING LINE CARDS

The procedure for hot swapping a line card consists of deactivating the line card, removing it from its slot in the RS chassis, and installing a new line card in the slot.

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4.2.1 Deactivating the Line Card

To deactivate the line card, do one of the following:

- Press the Hot Swap button on the line card. The Hot Swap button is recessed in the line card's front panel. Use a pen or similar object to reach it.

  When you press the Hot Swap button, the Offline LED lights. Figure 4-1 shows the location of the Offline LED and Hot Swap button on a 1000Base-SX line card.

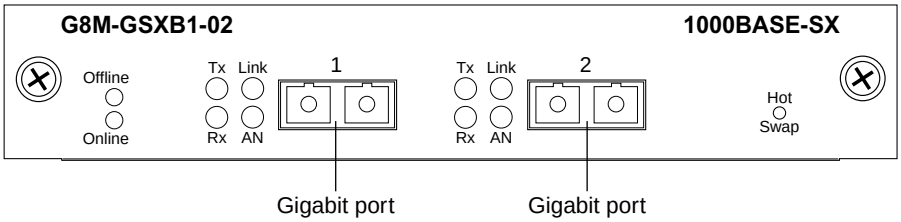

Figure 4-1 Location of offline LED and hot swap button on a 1000Base-SX line card

- Use the **system hotswap out** command in the CLI. For example, to deactivate the line card in slot 7, enter the following command in Enable mode:

```
rs# system hotswap out slot 7
```

After you enter this command, the Offline LED on the line card lights, and messages appear on the console indicating the ports on the line card are inoperative.

Note If you have deactivated a line card and want to activate it again, simply pull it from its slot and push it back in again. (Make sure the Offline LED is lit before you pull out the line card.) The line card is activated automatically.

Alternately, if you have not removed a line card you deactivated with the **system hotswap out** command, you can reactivate it with the **system hotswap in** command. For example, to reactivate a line card in slot 7, enter the following command in Enable mode:

```
rs# system hotswap in slot 7
```

4.2.2 Removing the Line Card

To remove a line card from the RS:

1. Make sure the Offline LED on the line card is lit.

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Warning Do not remove the line card unless the Offline LED is lit. Doing so can cause the RS to crash.

2. Loosen the captive screws on each side of the line card.
3. Carefully remove the line card from its slot in the RS chassis.

4.2.3 Installing a New Line Card

To install a new line card:

1. Slide the line card all the way into the slot, firmly but gently pressing the line card fully in place to ensure that the pins on the back of the line card are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

2. Tighten the captive screws on each side of the line card to secure it to the chassis.

   Once the line card is installed, the RS recognizes and activates it. The Online LED button lights.

4.3 HOT SWAPPING ONE TYPE OF LINE CARD WITH ANOTHER

You can hot swap one type of line card with another type. For example, you can replace a 10/100Base-TX line card with a 1000Base-SX line card. The RS can be configured to accommodate whichever line card is installed in the slot. When one line card is installed, configuration statements for that line card are used; when you remove the line card from the slot and replace it with a different type, configuration statements for the new line card take effect.

To set this up, you must include configuration statements for *both* line cards in the RS configuration file. The RS determines which line card is installed in the slot and uses the appropriate configuration statements.

For example, you may have an RS with a 10/100Base-TX line card in slot 7 and want to hot swap it with a 1000Base-SX line card. If you include statements for both line cards in the RS configuration file, the statements for the 1000Base-SX take effect immediately after you install it in slot 7.

4.4 HOT SWAPPING A SECONDARY CONTROL MODULE

If you have a secondary Control Module installed on the RS, you can hot swap it with another Control Module or line card.

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Warning You can only hot swap an *inactive* Control Module. You should never remove the active Control Module from the RS. Doing so will crash the system.

The procedure for hot swapping a Control Module is similar to the procedure for hot swapping a line card. You must deactivate the Control Module, remove it from the RS, and insert another Control Module or line card in the slot.

4.4.1 Deactivating the Control Module

To deactivate the Control Module:

1. Determine which is the secondary Control Module.

   Control Modules can reside in slot CM or slot CM/1 on the RS. Usually slot CM contains the primary Control Module, and slot CM/1 contains the secondary Control Module. On the primary Control Module, the Online LED is lit, and on the secondary Control Module, the Offline LED is lit.

Note The Offline LED on the Control Module has a different function from the Offline LED on a line card. On a line card, it means that the line card has been deactivated. On a Control Module, a lit Offline LED means that it is standing by to take over as the primary Control Module if necessary; it does *not* mean that the Control Module has been deactivated.

2. Press the Hot Swap button on the secondary Control Module.

   When you press the Hot Swap button, all the LEDs on the Control Module (including the Offline LED) are deactivated. Figure 4-2 shows the location of the Offline LED and Hot Swap button on a Control Module.

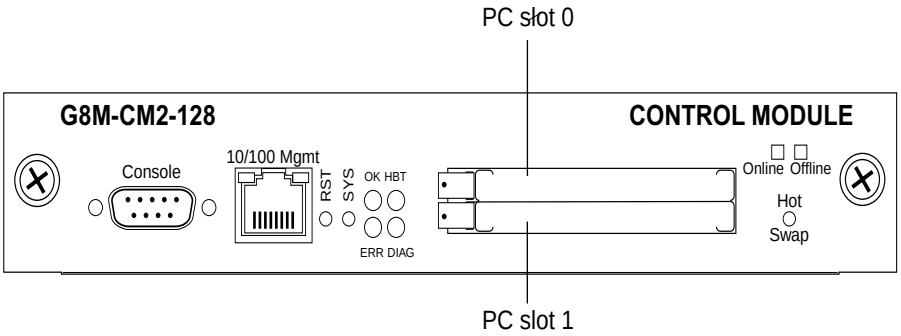

Figure 4-2 Location of offline LED and hot swap button on a control module

You can also use the **`system hotswap out`** command in the CLI to deactivate the Control Module. For example, to deactivate the secondary Control Module in slot CM/1, enter the following command in Enable mode:

```
rs# system hotswap out slot 1
```


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After you enter this command, the Offline LED on the Control Module lights, and messages appear on the console indicating the Control Module is inoperative.

4.4.2 Removing the Control Module

To remove a Control Module from the RS:

1. Make sure that *none* of the LEDs on the Control Module are lit.
2. Loosen the captive screws on each side of the Control Module.
3. Carefully remove the Control Module from its slot in the RS chassis.

4.4.3 Installing a Control Module

To install a new Control Module or line card into the slot:

Note You can install either a line card or a Control Module in slot CM/1, but you can install *only* a Control Module in slot CM.

1. Slide the Control Module or line card all the way into the slot, firmly but gently pressing it in place to ensure that the pins on the back of the card are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

2. Tighten the captive screws on each side of the Control Module or line card to secure it to the chassis.
   - On a line card, the Online LED lights, indicating it is now active.
   - On a secondary Control Module, the Offline LED lights, indicating it is standing by to take over as the primary Control Module if necessary.

4.5 HOT SWAPPING A SWITCHING FABRIC MODULE (RS 8600 ONLY)

The RS 8600 has slots for two Switching Fabric Modules. While the RS 8600 is operating, you can install a second Switching Fabric Module. If two Switching Fabric Modules are installed, you can hot swap one of them.

When you remove one of the Switching Fabric Modules, the other goes online and stays online until it is removed or the RS 8600 is powered off. When the RS 8600 is powered on again, the Switching Fabric Module in slot “Fabric 1,” if one is installed there, becomes the active Switching Fabric Module.

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Warning You can only hot swap a Switching Fabric Module if two are installed on the RS 8600. If only one Switching Fabric Module is installed, and you remove it, the RS 8600 will crash.

The procedure for hot swapping a Switching Fabric Module is similar to the procedure for hot swapping a line card or Control Module. You deactivate the Switching Fabric Module, remove it from the RS, and insert another Switching Fabric Module in the slot.

Note You cannot deactivate the Switching Fabric Module with the **`system hotswap`** command.

To deactivate the Switching Fabric Module:

1. Press the Hot Swap button on the Switching Fabric Module you want to deactivate.

   The Online LED goes out and the Offline LED lights. Figure 4-3 shows the location of the Offline LED and Hot Swap button on a Switching Fabric Module.

Figure 4-3 Location of offline LED and hot swap button on a switching fabric module

4.5.1 Removing the Switching Fabric Module

To remove the Switching Fabric Module:

1. Loosen the captive screws on each side of the Switching Fabric Module.
2. Pull the metal tabs on the Switching Fabric Module to free it from the connectors holding it in place in the chassis.
3. Carefully remove the Switching Fabric Module from its slot.

4.5.2 Installing a Switching Fabric Module

To install a Switching Fabric Module:

1. Slide the Switching Fabric Module all the way into the slot, firmly but gently pressing to ensure that the pins on the back of the module are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

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2. Tighten the captive screws on each side of the Switching Fabric Module to secure it to the chassis.

4.6 HOT SWAPPING A GBIC (RS 32000 AND RS 38000 ONLY)

The Gigabit Ethernet line cards have slots for GBICs that can be installed at any time. You can hot swap the GBICs installed in the line cards, as well as the line cards themselves. (For information on hot swapping line cards, see Section 4.2, *"Hot Swapping Line Cards."*)

Warning The GBIC and the host gigabit Ethernet line cards are sensitive to static discharge. Use an antistatic wrist strap and observe all static precautions when you remove or install a GBIC. Failure to do so could result in damage to the GBIC and the host line card. Always leave the GBIC in the antistatic bag or an equivalent antistatic container until it is ready to be installed.

4.6.1 Removing a GBIC from the Line Card

To remove a GBIC from its slot on the line card:

1. Remove any cables connected to the GBIC.
2. Locate the extractor tabs on either side of the GBIC.
3. Using thumb and forefinger, compress the extractor tabs on both sides of the GBIC and pull it out of the line card. See Figure 4-4.
4. If storing or shipping the GBIC, insert the rubber dust protector into the GBIC to protect the fiber ports.

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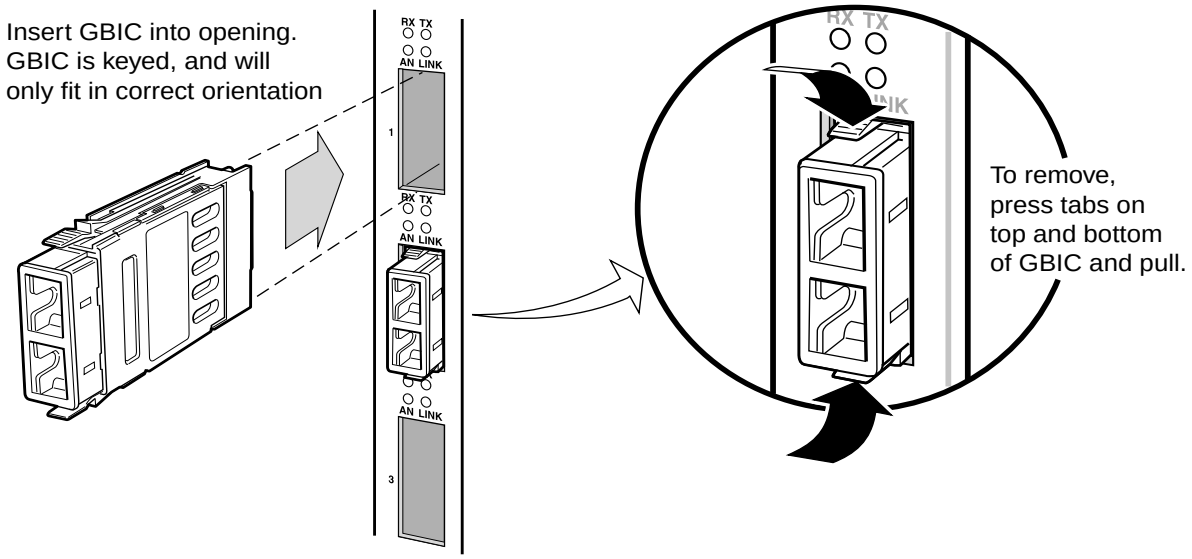

Figure 4-4 Installing and removing a GBIC.

4.6.2 Installing a GBIC into the Line Card

Install the GBIC into the line card as follows:

1. Hold the GBIC with the network port facing away from the line card. The 20-pin connector should be facing toward the empty GBIC slot of the line card.
2. The alignment slot on the GBIC must line up with the alignment guides inside the GBIC slot. The top of the GBIC must be next to the hinged side of the GBIC slot door of the line card.
3. Gently insert the GBIC module into the GBIC slot opening in the line card. The GBIC door on the line card folds in and the hinges engage the alignment slots on the sides of the GBIC module.

Note If the GBIC module does not go in easily, do not force it. If the GBIC is not oriented properly, it will stop about one quarter of the way into the slot and it should not be forced any further. Remove and reorient the GBIC module so that it slides easily into the slot.

4. Push the GBIC module in until the connector engages the 20-pin port. The GBIC is now installed.

4.7 HOT SWAPPING A WIC

Note Hot swapping WICs is not yet supported.

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5 BRIDGING CONFIGURATION GUIDE

The Riverstone RS Switch Router provides the following bridging functions:

- Compliance with the IEEE 802.1d standard
- Compliance with the IGMP multicast bridging standard
- Wire-speed address-based bridging or flow-based bridging
- Ability to logically segment a transparently bridged network into virtual local-area networks (VLANs), based on physical ports or protocol (IP or IPX or bridged protocols like Appletalk)
- Frame filtering based on MAC address for bridged and multicast traffic
- Integrated routing and bridging, which supports bridging of intra-VLAN traffic and routing of inter-VLAN traffic

5.1 SPANNING TREE (IEEE 802.1D)

Spanning tree (IEEE 802.1d) allows bridges to dynamically discover a subset of the topology that is loop-free. In addition, the loop-free tree that is discovered contains paths to every LAN segment.

5.2 BRIDGING MODES (FLOW-BASED AND ADDRESS-BASED)

The RS provides the following types of wire-speed bridging:

Address-based bridging - The RS performs this type of bridging by looking up the destination address in an L2 lookup table on the line card that receives the bridge packet from the network. The L2 lookup table indicates the exit port(s) for the bridged packet. If the packet is addressed to the RS' own MAC address, the packet is routed rather than bridged.

Flow-based bridging - The RS performs this type of bridging by looking up an entry in the L2 lookup table containing both the source and destination addresses of the received packet in order to determine how the packet is to be handled.

The RS ports perform address-based bridging by default but can be configured to perform flow-based bridging instead, on a per-port basis. A port cannot be configured to perform both types of bridging at the same time.

The RS performance is equivalent when performing flow-based bridging or address-based bridging. However, address-based bridging is more efficient because it requires fewer table entries while flow-based bridging provides tighter management and control over bridged traffic.

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5.3 VLAN OVERVIEW

Virtual LANs (VLANs) are a means of dividing a physical network into several logical (virtual) LANs. The division can be done on the basis of various criteria, giving rise to different types of VLANs. For example, the simplest type of VLAN is the port-based VLAN. Port-based VLANs divide a network into a number of VLANs by assigning a VLAN to each port of a switching device. Then, any traffic received on a given port of a switch *belongs* to the VLAN associated with that port.

VLANs are primarily used for broadcast containment. A layer-2 (L2) broadcast frame is normally transmitted all over a bridged network. By dividing the network into VLANs, the *range* of a broadcast is limited, i.e., the broadcast frame is transmitted only to the VLAN to which it belongs. This reduces the broadcast traffic on a network by an appreciable factor.

The type of VLAN depends upon one criterion: how a received frame is classified as belonging to a particular VLAN. VLANs can be categorized into the following types:

- Port based
- MAC address based
- Protocol based
- Subnet based
- Multicast based
- Policy based

Detailed information about these types of VLANs is beyond the scope of this manual. Each type of VLAN is briefly explained in the following subsections.

Port-based VLANs

Ports of L2 devices (switches, bridges) are assigned to VLANs. Any traffic received by a port is classified as belonging to the VLAN to which the port belongs. For example, if ports 1, 2, and 3 belong to the VLAN named “Marketing”, then a broadcast frame received by port 1 is transmitted on ports 2 and 3. It is not transmitted on any other port.

MAC-address-based VLANs

In this type of VLAN, each switch (or a central VLAN information server) keeps track of all MAC addresses in a network and maps them to VLANs based on information configured by the network administrator. When a frame is received at a port, its destination MAC address is looked up in the VLAN database. The VLAN database returns the name of the VLAN to which this frame belongs.

This type of VLAN is powerful in the sense that network devices such as printers and workstations can be moved anywhere in the network without the need for network reconfiguration. However, the administration is intensive because all MAC addresses on the network need to be known and configured.

Protocol-based VLANs

Protocol-based VLANs divide the physical network into logical VLANs based on protocol. When a frame is received at a port, its VLAN is determined by the protocol of the packet. For example, there could be separate VLANs for IP, IPX and Appletalk. An IP broadcast frame will only be sent to all ports in the IP VLAN.

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Subnet-based VLANs

Subnet-based VLANs are a subset of protocol based VLANs and determine the VLAN of a frame based on the subnet to which the frame belongs. To do this, the switch must look into the network layer header of the incoming frame. This type of VLAN behaves similar to a router by segregating different subnets into different broadcast domains.

Multicast-based VLANs

Multicast-based VLANs are created dynamically for multicast groups. Typically, each multicast group corresponds to a different VLAN. This ensures that multicast frames are received only by those ports that are connected to members of the appropriate multicast group.

Policy-based VLANs

Policy-based VLANs are the most general definition of VLANs. Each incoming (untagged) frame is looked up in a policy database, which determines the VLAN to which the frame belongs. For example, you could set up a policy which creates a special VLAN for all E-mail traffic between the management officers of a company, so that this traffic will not be seen anywhere else.

5.3.1 RS VLAN Support

The RS supports:

- Port-based VLANs
- Protocol-based VLANs
- Subnet-based VLANs

When using the RS as an L2 bridge/switch, use the port-based and protocol-based VLAN types. When using the RS as a combined switch and router, use the subnet-based VLANs in addition to port-based and protocol-based VLANs. It is not necessary to remember the types of VLANs in order to configure the RS, as seen in the section on configuring the RS.

VLANs and the RS

VLANs are an integral part of the RS family of switching routers. The RS switching routers can function as layer-2 (L2) switches as well as fully-functional layer-3 (L3) routers. Hence they can be viewed as a switch and a router in one box. To provide maximum performance and functionality, the L2 and L3 aspects of the RS switching routers are tightly coupled.

The RS can be used purely as an L2 switch. Frames arriving at any port are bridged and not routed. In this case, setting up VLANs and associating ports with VLANs is all that is required. You can set up the RS switching router to use port-based VLANs, protocol-based VLANs, or a mixture of the two types.

The RS can also be used purely as a router, i.e., each physical port of the RS is a separate routing interface. Packets received at any interface are routed and not bridged. In this case, no VLAN configuration is required. Note that VLANs are still created implicitly by the RS as a result of creating L3 interfaces for IP and/or IPX. However, these implicit VLANs do not need to be created or configured manually. The implicit VLANs created by the RS are subnet-based VLANs.

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Most commonly, an RS is used as a combined switch and router. For example, it may be connected to two subnets S1 and S2. Ports 1-8 belong to S1 and ports 9-16 belong to S2. The required behavior of the RS is that intra-subnet frames be bridged and inter-subnet packets be routed. In other words, traffic between two workstations that belong to the same subnet should be bridged, and traffic between two workstations that belong to different subnets should be routed.

The RS switching routers use VLANs to achieve this behavior. This means that a L3 subnet (i.e., an IP or IPX subnet) is mapped to a VLAN. A given subnet maps to exactly one and only one VLAN. With this definition, the terms *VLAN* and *subnet* are almost interchangeable.

To configure an RS as a combined switch and router, the administrator must create VLANs whenever multiple ports of the RS are to belong to a particular VLAN/subnet. Then the VLAN must be *bound to* an L3 (IP/IPX) interface so that the RS knows which VLAN maps to which IP/IPX subnet.

Ports, VLANs, and L3 Interfaces

The term *port* refers to a physical connector on the RS, such as an ethernet port. Each port must belong to at least one VLAN. When the RS is unconfigured, each port belongs to a VLAN called the "default VLAN." By creating VLANs and adding ports to the created VLANs, the ports are moved from the default VLAN to the newly created VLANs.

Unlike traditional routers, the RS has the concept of logical interfaces rather than physical interfaces. An L3 interface is a logical entity created by the administrator. It can contain more than one physical port. When an L3 interface contains exactly one physical port, it is equivalent to an interface on a traditional router. When an L3 interface contains several ports, it is equivalent to an interface of a traditional router which is connected to a layer-2 device such as a switch or bridge.

5.3.2 Configuration Examples

VLANs are used to associate physical ports on the RS with connected hosts that may be physically separated but need to participate in the same broadcast domain. To associate ports to a VLAN, you must first create a VLAN and then assign ports to the VLAN. This section shows examples of creating an IP or IPX VLAN and a DECnet, SNA, and AppleTalk VLAN.

Creating an IP or IPX VLAN

In this example, servers connected to port gi.1.(1-2) on the RS need to communicate with clients connected to et.4.(1-8). You can associate all the ports containing the clients and servers to an IP VLAN called 'BLUE'.

First, create an IP VLAN named 'BLUE'

```
rs(config)# vlan create BLUE ip
```

Next, assign ports to the 'BLUE' VLAN.

```
rs(config)# vlan add ports et.4.(1-8),gi.1.(1-2) to BLUE
```


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Creating a non-IP/non-IPX VLAN

In this example, SNA, DECnet, and AppleTalk hosts are connected to et.1.1 and et.2.(1-4). You can associate all the ports containing these hosts to a VLAN called 'RED' with the VLAN ID 5.

First, create a VLAN named 'RED'

```
rs(config)# vlan create RED sna dec appletalk id 5
```

Next, assign ports to the 'RED' VLAN.

```
rs(config)# vlan add ports et.1.1, et.2.(1-4) to RED
```

5.4 ACCESS PORTS AND TRUNK PORTS (802.1P AND 802.1Q SUPPORT)

The ports of an RS can be classified into two types, based on VLAN functionality: **access ports** and **trunk ports**. By default, a port is an access port. An access port can belong to at most one VLAN of the following types: IP, IPX or bridged protocols. The RS can automatically determine whether a received frame is an IP frame, an IPX frame or neither. Based on this, it selects a VLAN for the frame. Frames transmitted out of an access port contain no special information about the VLAN to which they belong. These frames are classified as belonging to a particular VLAN based on the protocol of the frame and the VLAN configured on the receiving port for that protocol.

For example, if port 1 belongs to VLAN *IPX_VLAN* for IPX, VLAN *IP_VLAN* for IP and VLAN *OTHER_VLAN* for any other protocol, then an IP frame received by port 1 is classified as belonging to VLAN *IP_VLAN*.

You can use the **`port enable 8021p`** command to tag frames transmitted from access ports with a one-byte, 802.1p class of service (CoS) value. The CoS value indicates the frame's priority. There are 8 CoS values, 0 is the lowest priority and 7 is the highest.

Trunk ports (802.1Q) are usually used to connect one VLAN-aware switch to another. They carry traffic belonging to several VLANs. For example, suppose that RS A and B are both configured with VLANs V1 and V2.

Then a frame arriving at a port on RS A must be sent to RS B, if the frame belongs to VLAN V1 or to VLAN V2. Thus the ports on RS A and B which connect the two RS's together must belong to both VLAN V1 and VLAN V2. Also, when these ports receive a frame, they must be able to determine whether the frame belongs to V1 or to V2. This is accomplished by "tagging" the frames, i.e., by prepending information to the frame in order to identify the VLAN to which the frame belongs. In the RS switching routers, trunk ports normally transmit and receive tagged frames only. (The format of the tag is specified by the IEEE 802.1Q standard.) If you configure Spanning Tree Protocol, frames are transmitted as untagged frames.

Explicit and Implicit VLANs

As mentioned earlier, VLANs can either be created explicitly by the administrator (explicit VLANs) or are created implicitly by the RS when L3 interfaces are created (implicit VLANs).

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5.5 CONFIGURING RS BRIDGING FUNCTIONS

5.5.1 Configuring Address-based or Flow-based Bridging

The RS ports perform address-based bridging by default but can be configured to perform flow-based bridging instead of address-based bridging, on a per-port basis. A port cannot be configured to perform both types of bridging at the same time.

The RS performance is equivalent when performing flow-based bridging or address-based bridging. However, address-based bridging is more efficient because it requires fewer table entries while flow-based bridging provides tighter management and control over bridged traffic.

For example, the following illustration shows a router with traffic being sent from port A to port B, port B to port A, port B to port C, and port A to port C.

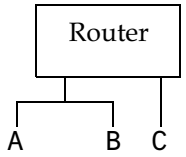

Figure 5-1 Router traffic going to different ports

The corresponding bridge tables for address-based and flow-based bridging are shown below. As shown, the bridge table contains more information on the traffic patterns when flow-based bridging is enabled compared to address-based bridging.

Address-Based Bridge Table	Flow-Based Bridge Table
A (source)	A → B
B (source)	B → A
C (destination)	B → C
	A → C

With the RS configured in flow-based bridging mode, the network manager has “per flow” control of layer-2 traffic. The network manager can then apply Quality of Service (QoS) policies or security filters based on layer-2 traffic flows.

To enable flow-based bridging on a port, enter the following command in Configure mode.

Configure a port for flow-based bridging.	**`port flow-bridging`** *<port-list>* **`|all-ports`**

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To change a port from flow-based bridging to address-based bridging, enter the following command in Configure mode:

Change a port from flow-based bridging to address-based bridging.	**negate** <*line-number of active config containing command*>: **port flow-bridging** <*port-list*> **|all-ports**

5.6 CONFIGURING SPANNING TREE

Note The ATM modules do not support Spanning Tree Protocol.

The RS supports per VLAN spanning tree. By default, all the VLANs defined belong to the default spanning tree. You can create a separate instance of spanning tree using the following command:

Create spanning tree for a VLAN.	**pvst create spanningtree** *vlan-name* <*string*>

By default, spanning tree is disabled on the RS. To enable spanning tree on the RS, you perform the following tasks on the ports where you want spanning tree enabled..

Enable spanning tree on one or more ports for default spanning tree.	**stp enable port** <*port-list*>
Enable spanning tree on one or more ports for a particular VLAN.	**pvst enable port** <*port-list*> **spanning-tree** <*string*>

5.6.1 Using Rapid STP

You can specify the use of "rapid" STP, defined by IEEE 802.1w. This protocol, also known as Fast Spanning Tree, is designed to reduce network recovery time.

Note RSTP works only on ports where STP is already enabled (with the **stp enable port** command).

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To enable rapid STP, enter the following command in Configure mode:

Enable rapid STP.	**stp set protocol-version rstp**

Note This command is not supported with per-VLAN spanning tree.

5.6.2 Adjusting Spanning-Tree Parameters

You may need to adjust certain spanning-tree parameters if the default values are not suitable for your bridge configuration. Parameters affecting the entire spanning tree are configured with variations of the bridge global configuration command. Interface-specific parameters are configured with variations of the bridge-group interface configuration command.

Note Only network administrators with a good understanding of how bridges and the Spanning-Tree Protocol work should make adjustments to spanning-tree parameters. Poorly chosen adjustments to these parameters can have a negative impact on performance. A good source on bridging is the IEEE 802.1d specification.

Setting the Bridge Priority

You can globally configure the priority of an individual bridge when two bridges tie for position as the root bridge, or you can configure the likelihood that a bridge will be selected as the root bridge. The lower the bridge's priority, the more likely the bridge will be selected as the root bridge. This priority is determined by default; however, you can change it.

To set the bridge priority, enter the following command in Configure mode:

Set the bridge priority for default spanning tree.	**stp set bridging priority** <*num*>
Set the bridge priority for a particular instance of spanning tree.	**pvst set bridging spanning-tree** <*string*> **priority** <*num*>

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Setting a Port Priority

You can set a priority for an interface. When two bridges tie for position as the root bridge, you configure an interface priority to break the tie. The bridge with the lowest interface value is elected.

To set an interface priority, enter the following command in Configure mode:

Establish a priority for a specified interface for default spanning tree.	**stp set port** *<port-list>* **priority** *<num>*
Establish a priority for a specified interface for a particular instance of spanning tree.	**pvst set port** *<port-list>* **spanning-tree** *<string>* **priority** *<num>*

Assigning Port Costs

Each interface has a port cost associated with it. By convention, the port cost is 1000/data rate of the attached LAN, in Mbps. You can set different port costs.

To assign port costs, enter the following command in Configure mode:

Set a different port cost other than the defaults for default spanning tree.	**stp set port** *<port-list>* **port-cost** *<num>*
Set a different port cost other than the defaults for a particular instance of spanning tree.	**pvst set port** *<port-list>* **spanning-tree** *<string>* **port-cost** *<num>*

Adjusting Bridge Protocol Data Unit (BPDU) Intervals

You can adjust BPDU intervals as described in the following sections:

- Adjust the Interval between Hello BPDUs
- Define the Forward Delay Interval
- Define the Maximum Idle Interval

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Adjusting the Interval between Hello Times

You can specify the interval between hello time. To adjust this interval, enter the following command in Configure mode:

Specify the interval between hello time for default spanning tree.	**stp set bridging hello-time** <*num*>
Specify the interval between hello times for a particular instance of spanning tree.	**pvst set bridging spanning-tree** <*string*> **hello-time** <*num*>

Defining the Forward Delay Interval

The forward delay interval is the amount of time spent listening for topology change information after an interface has been activated for bridging and before forwarding actually begins.

To change the default interval setting, enter the following command in Configure mode:

Set the default of the forward delay interval for default spanning tree.	**stp set bridging forward-delay** <*num*>
Set the default of the forward delay interval for a particular instance of spanning tree.	**pvst set bridging spanning-tree** <*string*> **forward-delay** <*num*>

Defining the Maximum Age

If a bridge does not hear BPDUs from the root bridge within a specified interval, it assumes that the network has changed and recomputes the spanning-tree topology.

To change the default interval setting, enter the following command in Configure mode:

Change the amount of time a bridge will wait to hear BPDUs from the root bridge for default spanning tree.	**stp set bridging max-age** <*num*>
Change the amount of time a bridge will wait to hear BPDUs from the root bridge for a particular instance of spanning tree.	**pvst set bridging spanning-tree** <*string*> **max-age** <*num*>

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5.6.3 STP Dampening

STP creates a loop free, active topology in a network by placing ports in a forwarding or blocking state. When a port moves to the forwarding state, it transitions from listening, to learning, and then to forwarding. Whenever this transition happens, there is a chance that some traffic may be lost. If this port state transition happens rarely, the traffic loss is insignificant. On the other hand, if this happens frequently, it can adversely affect the network. STP dampening addresses this issue.

When a root port stops receiving BPDUs from the root bridge, a new root port is selected. If the original root port starts receiving BPDUs from the root bridge once again and STP dampening is enabled on the port, traffic is not immediately switched back to it. Instead, the port is monitored until it satisfes a stability condition, which is that it receives a certain number of STP configuration BPDUs during a specified period of time. If the port satisfies this condition, then it is considered stable and traffic is switched back to it. Otherwise, it remains in an unstable state and is continuously monitored until it satisfies the stability condition. This feature ensures that ports are stable before they move to a forwarding state and traffic is switched back to them.

Note that dampening will not occur if the port on which STP dampening is enabled goes down and comes up again. Instead, traditional STP configuration occurs.

To enable STP dampening on a port, enter the following command in Configure mode:

Enable STP dampening on a port.	**stp set port** *<port-list>* **dampening enable**

Note STP dampening cannot be used in conjunction with RSTP.

The RS has defaults for the period of time a port will be monitored (10 seconds) and the number of BPDUs that need to be received (10) during this period. You can change these defaults by entering the following command in Configure mode:

Set parameters for STP dampening.	**stp set bridging damp-monitor-time** *<seconds>* **damp-bpdu-count** *<number>*

5.7 CONFIGURING A PORT- OR PROTOCOL-BASED VLAN

To create a port or protocol based VLAN, perform the following steps in the Configure mode.

1. Create a port or protocol based VLAN.
2. Add physical ports to a VLAN.

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5.7.1 Creating a Port or Protocol Based VLAN

To create a VLAN, enter the following command in Configure mode.

Create a VLAN.	**vlan create** *<vlan-name> <type>* **id** *<num>*

5.7.2 Adding Ports to a VLAN

To add ports to a VLAN, enter the following command in Configure mode.

Add ports to a VLAN.	**vlan add ports** *<port-list>* **to** *<vlan-name>*

Note The ATM modules do not support Spanning Tree Protocol. Therefore be careful to not put loops within the VLAN.

5.7.3 Configuring VLAN Trunk Ports

The RS supports standards-based VLAN trunking between multiple RS's as defined by IEEE 802.1Q. 802.1Q adds a header to a standard Ethernet frame which includes a unique VLAN ID per trunk between two RS's. These VLAN IDs extend the VLAN broadcast domain to more than one RS.

To configure a VLAN trunk, enter the following command in the Configure mode.

Configure 802.1Q VLAN trunks.	**vlan make** *<port-type> <port-list>*

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You can enable the collection of VLAN statistics on 10/100 and Gigabit Ethernet ports configured as 802.1Q trunk ports. To do so, use the **`port enable per-vlan-stats`** command. Then, you can display the statistics by using the **`port show per-vlan-stats`** command as illustrated in the following example:

```
rs# port show per-vlan-stats port et.10.4
Traffic Statistics for Port et.10.4, VLAN red (VLAN ID 2):
Inbound
   Octets:                 107,196,271 octets
   Frames:                     134,940 frames

Outbound
   Octets:                 105,965,469 octets
   Frames:                     133,549 frames

Traffic Statistics for Port et.10.4, VLAN blue (VLAN ID 3):
Inbound
   Octets:                 354,072,575 octets
   Frames:                     446,763 frames

Outbound
   Octets:                 347,463,892 octets
   Frames:                     435,218 frames
```

5.8 CONFIGURING VLANS FOR BRIDGING

The RS allows you to create VLANs for AppleTalk, DECnet, SNA, and IPv6 traffic as well as for IP and IPX traffic. You can create a VLAN for handling traffic for a single protocol, such as a DECnet VLAN. Or, you can create a VLAN that supports several specific protocols, such as SNA and IP traffic.

Note Some commands in this facility require updated RS hardware.

5.9 CONFIGURING LAYER-2 FILTERS

Layer-2 security filters on the RS allow you to configure ports to filter specific MAC addresses. When defining a Layer-2 security filter, you specify to which ports you want the filter to apply. For details on configuring Layer-2 filters, refer to Chapter 25, *"Security Configuration."* You can specify the following security filters:

- Address filters

  These filters block traffic based on the frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Address filters are always configured and applied to the input port.

- Port-to-address lock filters

  These filters prohibit a user connected to a locked port or set of ports from using another port.

- Static entry filters

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These filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port.

- Secure port filters

  A secure filter shuts down access to the RS based on MAC addresses. All packets received by a port are dropped. When combined with static entries, however, these filters can be used to drop all received traffic but allow some frames to go through.

5.10 MONITORING BRIDGING

The RS displays bridging statistics and configurations contained in the RS.

To display bridging information, enter the following commands in Enable mode.

Show IP routing table.	**ip show routes**
Show all MAC addresses currently in the l2 tables.	**l2-tables show all-macs**
Show l2 table information on a specific port.	**l2-tables show port-macs**
Show information the master MAC table.	**l2-tables show mac-table-stats**
Show information on a specific MAC address.	**l2-tables show mac**
Show information on MACs registered.	**l2-table show bridge-management**
Show all VLANs.	**vlan show**

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5.11 GARP/GVRP

The Generic Attribute Registration Protocol (GARP) is a generic attribute dissemination mechanism. In the case of the GARP VLAN Registration Protocol (GVRP), the attribute is the VLAN ID (VID).

GVRP uses GARP Protocol Data Units (PDUs) to register and de-register VLAN IDs on ports. When you enable GVRP on the RS and one of its ports receives a GVRP request for an existing VLAN to which it does *not* belong, GVRP registers the VLAN ID on the port, effectively adding the port to the VLAN. For example, VLAN RED is configured on ports et.1.1 and et.1.2 of the RS. Port et.1.3 receives a GVRP request for VLAN RED, of which it is not a member. If GVRP is enabled on port et.1.3, it will autmoatically become a member of VLAN RED and pass traffic for this VLAN. But if GVRP is *not* enabled on port et.1.3, VLAN registration will not occur, and traffic for VLAN RED will never reach port et.1.3.

GVRP also provides a mechanism for dynamically creating and removing VLANs. When you turn on dynamic VLAN creation and the RS receives a request for a VLAN that does not exist on the RS, GVRP dynamically creates that VLAN and adds the port that received the request.

GVRP propagates this VLAN information throughout the active topology, enabling all GVRP-aware devices to dynamically establish and update their knowledge of VLANS and their members, including the ports through which those members can be reached. (For details on GARP refer to IEEE 802.1d. For details on GVRP, refer to IEEE 802.1q.)

Note GVRP will only add a port to a VLAN if the port is an 802.1q trunk port.

GARP/GVRP provides the following benefits:

- The administrator is not required to know ahead of time which VLANS should be configured on the network.
- The administrator does not have to manually configure all VLANS on the network.
- It prunes unnecessary traffic if a VLAN goes down.

5.11.1 Running GARP/GVRP with STP

Anytime GARP /GVRP configures a VLAN or adds ports to a VLAN, this information needs to be propagated on all other ports that are part of the active topology. If STP is disabled, this includes all ports, except the input port. If STP is enabled, this includes all ports that are in the forwarding mode, except the input port.

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5.11.2 Configuring GARP/GVRP

To configure GARP/GVRP on the RS, you should do the following:

1. Enable GVRP functionality on the RS. (GVRP is disabled on the RS by default.)
2. Enable GVRP on individual ports. (GVRP is disabled on all ports on the RS by default.)

You can optionally set the following features by using the **`garp`** and **`gvrp`** commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*:

- Enable dynamic VLAN creation. (This feature is disabled by default.) When you enable this feature, VLANs will be created dynamically when there is a GVRP request for a VLAN that does not exist on the RS. In addition, you will still be able to configure VLANs manually through the CLI.
- Set a port's registration mode to *forbidden*. Registration modes refer to whether VLAN IDs can be dynamically registered or de-registered on a port. You can set a port's mode to forbidden to prevent it from being dynamically added to a VLAN. Setting a port to "forbidden registration" de-registers all VLANS (except VLAN 1) and prevents further VLAN registration on the port.
- Set a port's status to *non-participating*. When you do so, the specified ports will not send GARP PDUs.
- Change the default values for the following GARP timers:
  - leaveall timer default is 10,000 ms
  - leave timer default is 600 ms (When configuring the leave timer, its value should be three times that of the join timer.)
  - join timer default is 200 ms

Note For GARP to operate properly, all layer-2 connected devices should have the same GARP timer values.

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5.11.3 Configuration Example

Consider the following configuration example.

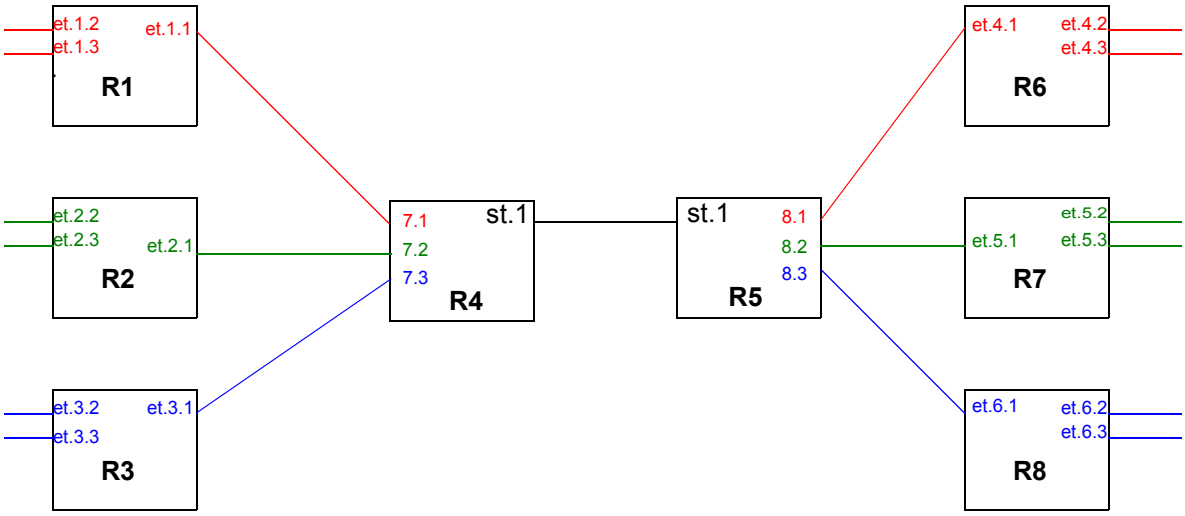

Figure 5-2 Using GARP/GVRP on a network

Routers R4 and R5 pass traffic between two networks. The administrator used the CLI to configure the following VLANs:

- VLAN RED on ports et.1.1- 1.3 on R1, and on et.4.1 - 4.3 on R6.
- VLAN GREEN on ports et.2.1- 2.3 on R2, and on et.5.1 - 5.3 on R7.
- VLAN BLUE on ports et.3.1- 3.3 on R3, and on et.6.1 - 6.3 on R8.

No VLANs were configured on R4 and R5. Instead, dynamic VLAN creation was enabled. So when any of the edge routers (R1, R2, R3, R6, R7, or R8) send a request for a VLAN to the core routers (R4 and R5), and the VLAN does not exist on the core routers, that VLAN is dynamically created on the port of the router that received the request.

For example, R4 receives a receives a request for VLAN RED on port 7.1. VLAN RED is created dynamically on port 7.1 of R4. This is then propagated across the bridged LAN to all the other routers. If dynamic VLAN creation was not enabled on R4, it would have dropped the traffic for VLAN RED.

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The following is the configuration for R1:

Create VLAN RED as a port-based VLAN and add ports to it.

```
vlan create red port-based
vlan add ports et.1.1-3 to vlan red
```

Enable GVRP

```
gvrp start
```

Enable GVRP on ports et.1.1-3.

```
gvrp enable ports et.1.1-3
```

Ports et.1.2 and 1.3 do not need to send GARP PDUs because they are connected to devices that are not running GVRP. Therefore, we should set their status to non-participating.

```
gvrp set applicant status non-participant et.1.2-3
```

The following is the configuration for R4:

Create the SmartTRUNK.

```
smarttrunk create st.1 protocol no-protocol
```

Add ports to the SmartTRUNK.

```
smarttrunk add ports et.1.1-3 to st.1
```

Enable GVRP

```
gvrp start
```

Enable GVRP on ports st.1, and et.7.1-3.

```
gvrp enable ports st.1, et.7.1-3
```

Enable dynamic VLAN creation so when R1, R2, or R3 sends a request for a VLAN, it will dynamically be created on R4.

```
gvrp enable dynamic vlan-creation
```

Note that because dynamic VLAN creation was enabled on R4, we did not have to manually configure any VLAN on R4.

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5.12 TUNNELING VLAN PACKETS ACROSS MANS

The "stackable" VLAN feature on the RS allows you to tunnel multiple VLANs through a metropolitan area network (MAN) over a single backbone VLAN. This feature provides the following benefits:

- Traffic for multiple VLANs, or traffic for multiple customers, can be aggregated to run through a MAN over a single backbone VLAN. The RS supports a maximum of 4094 customers or VLANs and up to 4094 backbone VLANs.
- Spanning tree and rapid spanning tree protocols can be run in customer-specific VLANs; no reconfiguration of customer-specific VLANs is needed.
- Per-VLAN spanning tree can be run in the backbone VLAN.

5.12.1 Stackable VLAN Components

The following figure illustrates the basic components of the stackable VLAN. Routers R1 and R2 switch traffic for customers C1 and C2 through the MAN. Ports et.2.1 on R1 and et.6.1 on R2 belong to customer C1's VLAN, "BLUE" while ports et.3.1 on R1 and et. 7.1 on R2 belong to customer C2's VLAN, "GREEN." Traffic entering any of these four ports are tagged with the appropriate customer VLAN ID (BLUE or GREEN) in an IEEE 802.1q header.

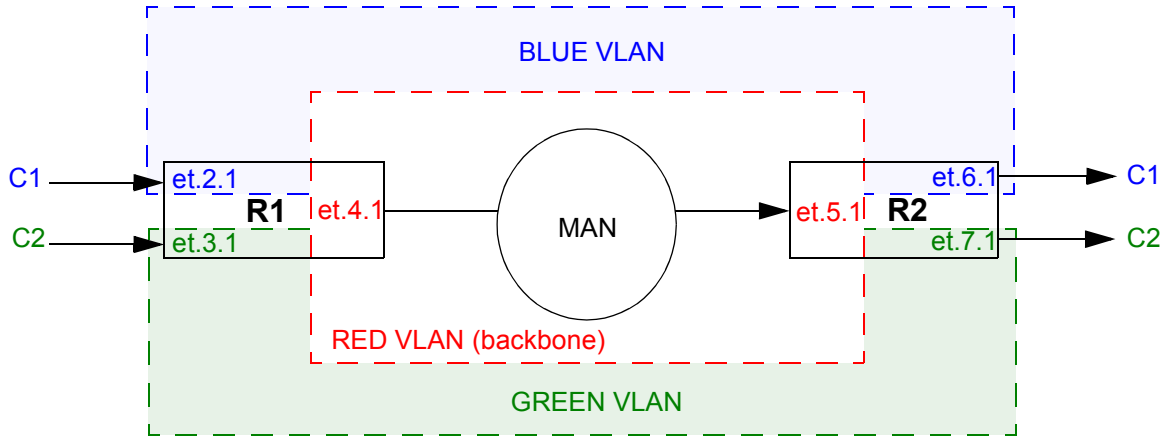

Figure 5-3 Stackable VLAN components

- The VLAN RED is the *backbone VLAN*, which allows traffic from various VLANs to be tunneled through the MAN.
- Ports et.4.1 on R1 and et.5.1 on R2 are *tunnel backbone ports*, which are trunk ports through which the VLAN traffic is tunneled. Tunnel backbone ports must be configured as trunk ports so that they maintain the encapsulated 802.1q header. You configure these ports as both trunk ports and tunnel backbone ports with the **`stackable-vlan`** option of the **`vlan make trunk-port`** CLI command.
- Ports et.2.1 and et.3.1 on R1 are *tunnel entry ports*, which are access ports on which the VLAN traffic to be tunneled enters R1. Ports et. 6.1 and et.7.1 on R2 are *tunnel exit ports*, which are access ports on which the tunneled traffic exits R2. You configure the mapping of the tunnel entry and tunnel exit ports to the backbone VLAN with the **`vlan enable stackable-vlan`** CLI command.

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Note Tunnel entry and exit port are configured as access ports. These ports can receive 802.1q-tagged traffic.

In Figure 5-3, customer C1 tags outgoing traffic with the VLAN ID BLUE in the 802.1q headers. Customer C1's traffic enters the tunnel entry port et.2.1 on R1. On R1, the tunnel entry port et.2.1 is mapped to the backbone VLAN RED. The BLUE-tagged packet received on port et.2.1 is encapsulated with an 802.1q header with VLAN RED's tag before it is bridged out on the tunnel backbone port et.4.1. (The original 802.1q header with the VLAN BLUE ID is now part of the data portion of the packet.) On R2, the RED 802.1q header is stripped off before the packet is sent out on et.6.1. The packet is sent out the tunnel exit port as a tagged packet with the original BLUE 802.1q header.

If an untagged packet arrives on a tunnel entry port, normal layer 2 processing takes place. If the packet needs to be flooded, it will be flooded on all ports in the customer VLAN.

If a broadcast or multicast packet arrives on a tunnel entry port, the packet is flooded on all ports that belong to the backbone VLAN as well as any other ports that belong to that VLAN. If a unicast packet arrives on a tunnel entry port, the packet is sent out a particular backbone VLAN port.

The 802.1p priority of a packet is preserved throughout the MAN. The RS hardware uses the control priority in the L2 table entry. If there is no L2 table entry for the packet, the 802.1p priority contained in the 802.1q header is used.

Normally, access ports can belong to only one VLAN of a particular protocol type, such as IP. The RS allows tunnel entry and exit ports to be added to multiple VLANs. Note, however, that only ports that are configured with the **`stackable-vlan`** option of the **`vlan make access-port`** command can be added to more than one VLAN of the same protocol type.

GARP and/or GVRP can be enabled on tunnel backbone ports.

Note You *cannot* enable L4 bridging on stackable VLANs. Also, do not use the **`stp set vlan-disable`** command on routers where you are configuring stackable VLANs.

5.12.2 Configuration Examples

This section contains configuration examples for the following scenarios:

- Multiple customers, with each customer having its own VLAN
- Multiple customers sharing a common VLAN
- Single VLAN with multiple tunnel entry ports
- STP or GVRP in customer VLANs tunneled over the backbone VLAN
- Multiple VLANs on a single tunnel entry/exit port

Multiple Customer VLANs

In Figure 5-4, traffic for customer C1's VLAN (BLUE) and for customer C2's VLAN (GREEN) is tunneled through the backbone VLAN (RED).

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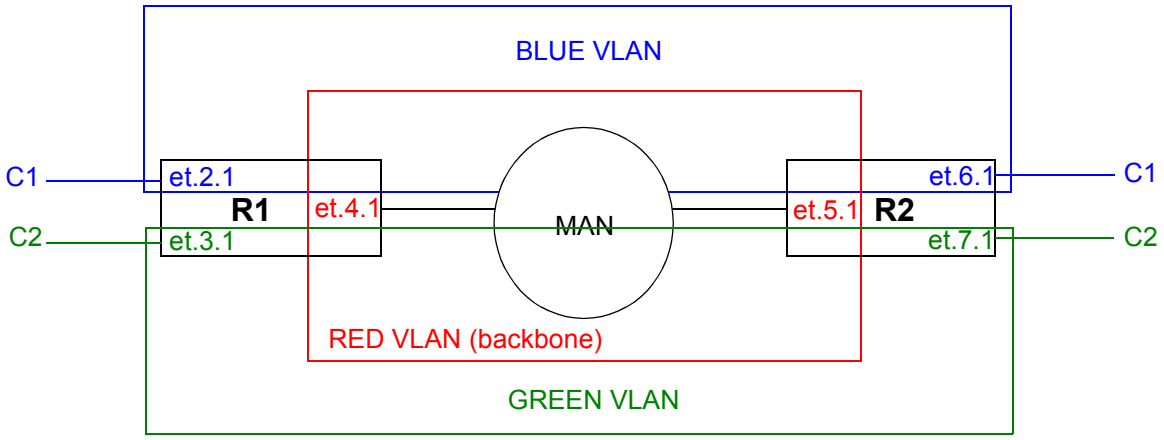

Figure 5-4 Multiple customers with different VLANs

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```


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The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to GREEN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

Multiple Customers with Common VLANs

In Figure 5-5, customers C1 and C2 are connected to the MAN, with both customers using the same VLAN (BLUE). To ensure that traffic for C1 is not sent to C2 and vice versa, the backbone VLAN for each customer must be different. Therefore, traffic for customer C1 will be sent on the backbone VLAN RED, while traffic for customer C2 will be sent on the backbone VLAN GREEN. Note that the trunk port on each router is part of both backbone VLAN RED and backbone VLAN GREEN.

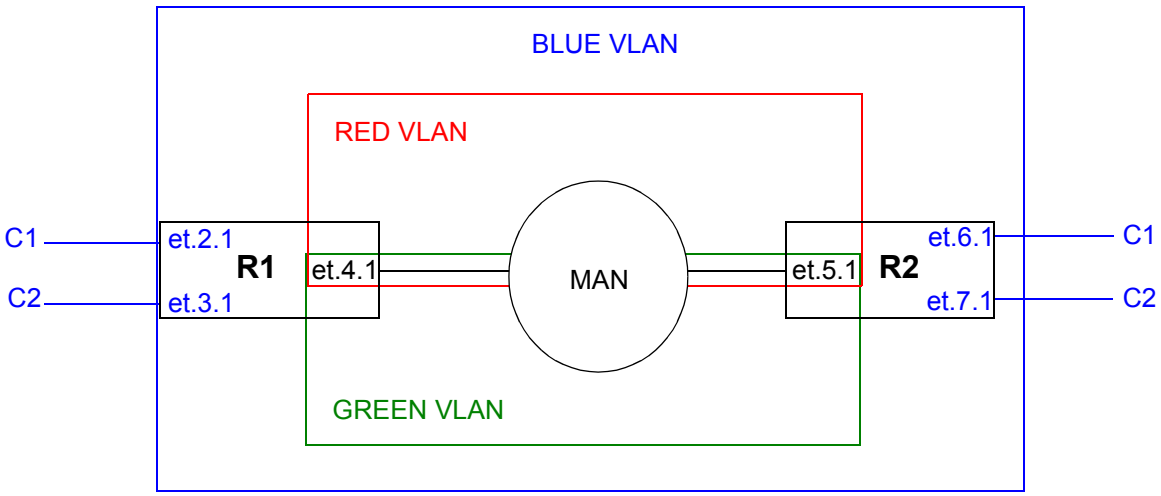

Figure 5-5 Multiple customers with common VLANs

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The following is the configuration for R1:

```
! Create 2 backbone VLANs and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to BLUE VLAN
vlan add ports et.2.1, et.3.1 to BLUE
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Add et.4.1 to both RED and GREEN backbone VLANs
vlan add ports et.4.1 to RED
vlan add ports et.4.1 to GREEN
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan GREEN
```

The following is the configuration for R2:

```
! Create 2 backbone VLANs and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to BLUE VLAN
vlan add ports et.6.1, et.7.1 to BLUE
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Add et.5.1 to both RED and GREEN backbone VLANs
vlan add ports et.5.1 to RED
vlan add ports et.5.1 to GREEN
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan GREEN
```

Tunnel entry or exit ports can be spread across routers. In Figure 5-6, customers C1 and C3 use the VLAN BLUE, while customers C2 and C4 use the VLAN GREEN. The backbone VLAN for each customer must be different to ensure that traffic for C1 is not sent to C3, traffic for C2 is not sent to C4, etc. Therefore, traffic for customer C1 and C2 will be sent on the backbone VLAN RED, while traffic for customer C3 and C4 will be sent on the backbone VLAN PURPLE.

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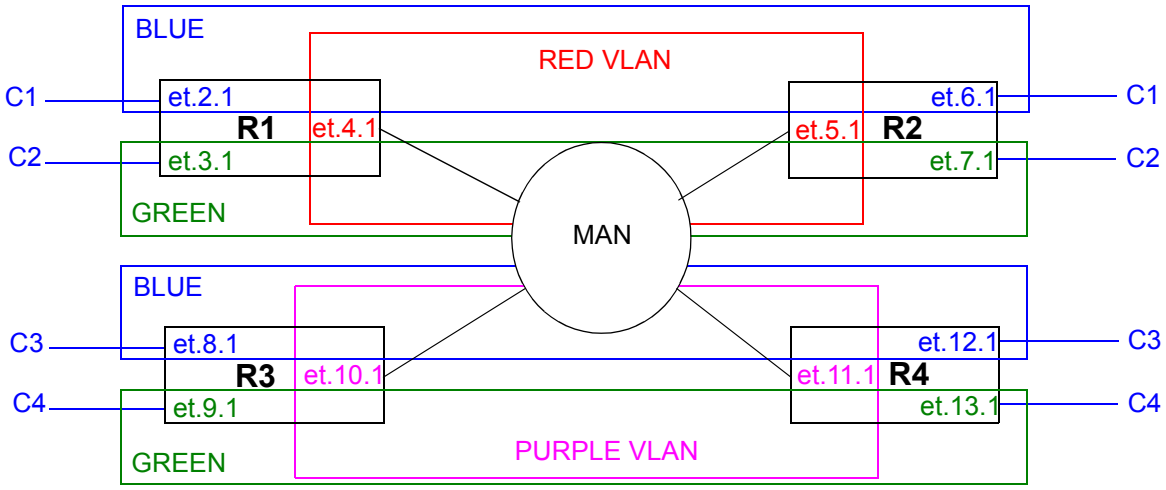

Figure 5-6 Multiple customers with common VLANs across multiple routers

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```


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The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.5.1 to RED
vlan add ports et.7.1 to GREEN
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

The following is the configuration for R3:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create PURPLE port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.8.1 to BLUE
vlan add ports et.9.1 to GREEN
vlan add ports et.10.1 to PURPLE
! Make et.10.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.10.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.8.1 backbone-vlan PURPLE
vlan enable stackable-vlan on et.9.1 backbone-vlan PURPLE
```


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The following is the configuration for R4:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create PURPLE port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.11.1 to PURPLE
vlan add ports et.12.1 to BLUE
vlan add ports et.13.1 to GREEN
! Make et.11.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.11.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.12.1 backbone-vlan PURPLE
vlan enable stackable-vlan on et.13.1 backbone-vlan PURPLE
```

Single VLAN with Multiple Tunnel Entry Ports

In Figure 5-7, customer C1 has a VLAN BLUE with multiple tunnel entry ports (et.2.1 and et.3.1 on R1) and multiple tunnel exit ports (et.6.1 and et.7.1 on R2).

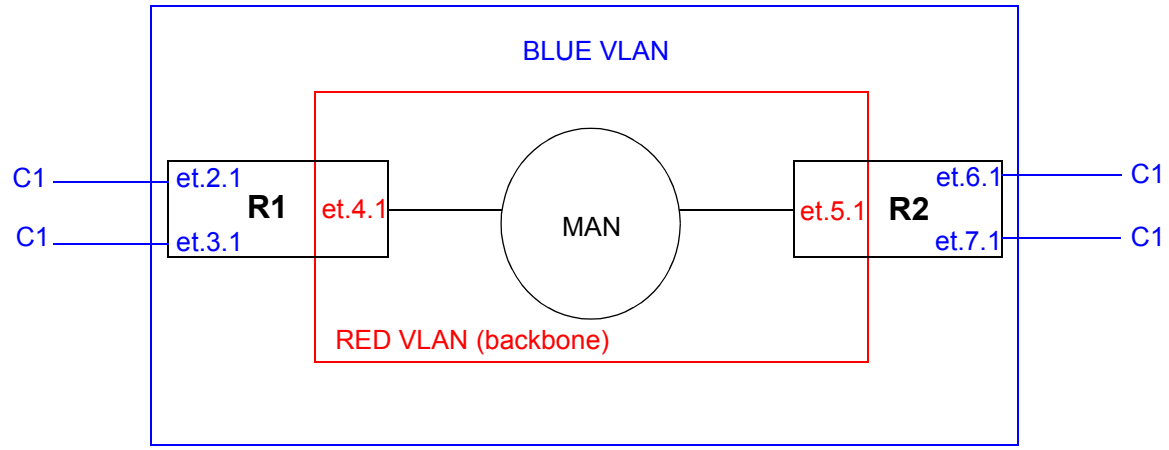

Figure 5-7 Customer VLAN with multiple tunnel entry/exit ports

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The following is the configuration for R1:

```
! Create backbone VLAN and customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to VLANs
vlan add ports et.2.1, et.3.1 to BLUE
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create backbone VLAN and customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to VLANs
vlan add ports et.6.1, et.7.1 to BLUE
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

The following is an example where a customer VLAN has multiple tunnel entry or exit ports spread across routers. Figure 5-8 shows customers C1 and C2 sharing the VLAN BLUE. Traffic for customer C1 can arrive on tunnel entry ports on routers R1, R2, or R3. Broadcast or multicast traffic arriving on et.2.1 on R1 is tunneled on backbone VLAN RED and will be seen by C1 users on R2 and R3. C2 users on R4 will not see the C1 traffic since the tunnel backbone port on R4 belongs to the backbone VLAN PURPLE.

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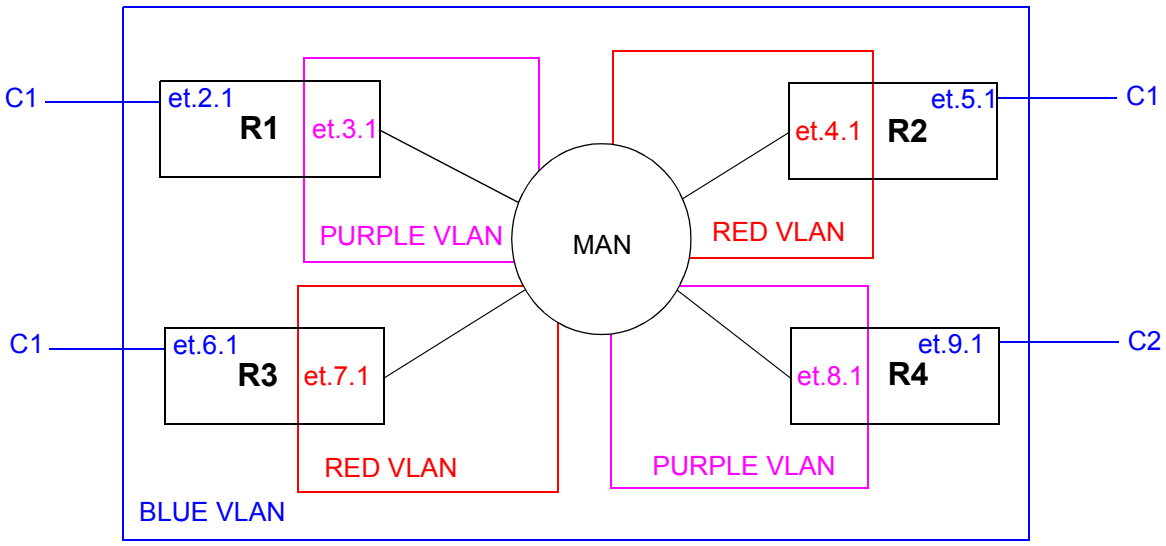

Figure 5-8 Customer VLAN with multiple tunnel entry ports across multiple routers

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create PURPLE port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to PURPLE
! Make et.3.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.3.1 stackable-vlan
! Map tunnel entry port to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan PURPLE
```


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The following is the configuration for R2:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.4.1 to RED
vlan add ports et.5.1 to BLUE
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.5.1 backbone-vlan RED
```

The following is the configuration for R3:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to RED
! Make et.7.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.7.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
```

The following is the configuration for R4:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create PURPLE port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.8.1 to PURPLE
vlan add ports et.9.1 to BLUE
! Make et.8.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.8.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.9.1 backbone-vlan PURPLE
```


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Note If you do not want multicast or broadcast traffic from C1 on R1 to be seen by C1 on R3, then configure a different backbone VLAN on R3.

STP/GVRP in Customer VLANs Tunneled over Backbone VLAN

STP, RSTP, or GARP/GVRP can be run in the customer VLANs which are tunneled over the backbone VLAN. The customer VLAN does not need to be reconfigured in order to be tunneled.

In Figure 5-9, traffic for customer C1's VLAN (BLUE) and for customer C2's VLAN (GREEN) is tunneled through the backbone VLAN (RED). STP is enabled in the customer VLAN BLUE on the customer routers C1R1 and C1R2 for customer C1.

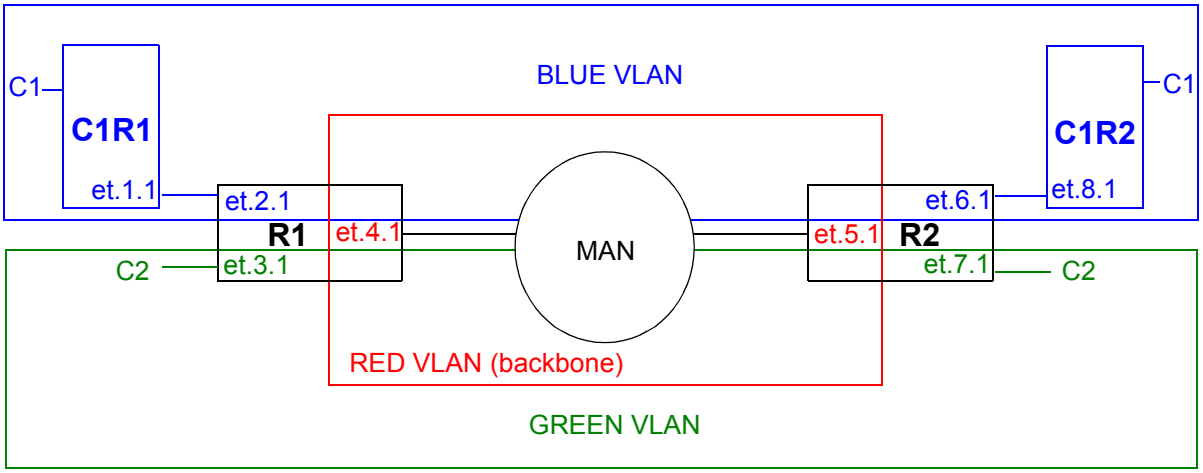

Figure 5-9 STP enabled in customer VLANs

The following configuration statements on C1R1 enable STP on port et.1.1, the port that is connected to the tunnel entry port.

```
! Create customer VLAN
vlan create BLUE port-based
! Add port to VLAN
vlan add ports et.1.1 to BLUE
! Make port et.1.1 a trunk port
vlan make trunk-port et.1.1
! Enable STP on et.1.1
stp enable port et.1.1
! Optional STP configurations
stp set bridging hello-time 3
```


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The following configuration statements on C1R2 enable STP on port et.8.1, the port that is connected to the tunnel exit port.

```
! Create customer VLAN
vlan create BLUE port-based
! Add port to VLAN
vlan add ports et.8.1 to BLUE
! Make port et.8.1 a trunk port
vlan make trunk-port et.8.1
! Enable STP on et.8.1
stp enable port et.8.1
```

The configuration of the tunnel entry/exit ports and tunnel backbone ports on R1 and R2 are identical to those shown in the earlier example in Figure 5-4:

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```


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The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to GREEN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

Multiple VLANs on a Single Tunnel Entry Port

Tunnel entry and exit ports are access ports. Normally, access ports can belong to only one VLAN of a particular protocol type. With stackable VLANs, traffic for multiple VLANs can enter a tunnel entry port to be tunneled over the backbone VLAN. In this case, the tunnel entry port must belong to all the VLANs that are to be tunneled. Use the **stackable-vlan** option of the **vlan make access-port** command to allow the tunnel entry port to be added to any number of VLANs.

In Figure 5-10, customers C1, C2, C3, C4, and C5 each have a VLAN that will use port et.2.1 on R1 as the tunnel entry port. On R2, port et.6.1 will be the tunnel exit port for traffic for all five VLANs.

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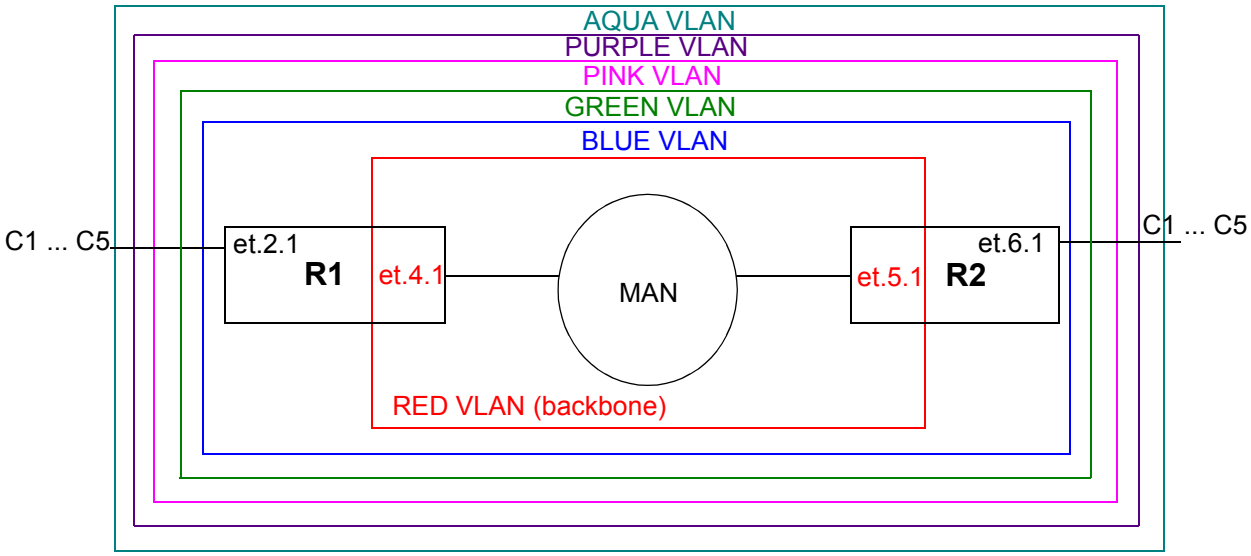

Figure 5-10 Multiple VLANs on single tunnel entry port

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The following is the configuration for R1:

```
! Create backbone VLAN
vlan create RED port-based
! Create customer VLANs
vlan create BLUE port-based
vlan create GREEN port-based
vlan create PINK port-based
vlan create PURPLE port-based
vlan create AQUA port-based
! Make et.2.1 an access port that can belong to > 1 VLAN
vlan make access-port et.2.1 stackable-vlan
! Add ports to VLANs
vlan add ports et.2.1 to BLUE
vlan add ports et.2.1 to GREEN
vlan add ports et.2.1 to PINK
vlan add ports et.2.1 to PURPLE
vlan add ports et.2.1 to AQUA
! Add port to backbone VLAN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

Note Note that in the above configuration, the commands that add port et.2.1 to more than one VLAN must be issued *before* the command to map the port to the backbone VLAN. That is, the **`vlan add ports`** commands must occur *before* the **`vlan enable stackable-vlan`** command. Once the **`vlan enable stackable-vlan`** command is issued, ports cannot be added to or removed from the customer VLANs.

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The following is the configuration for R2:

```
! Create backbone VLAN
vlan create RED port-based
! Create customer VLANs
vlan create BLUE port-based
vlan create GREEN port-based
vlan create PINK port-based
vlan create PURPLE port-based
vlan create AQUA port-based
! Make et.6.1 an access port that can belong to > 1 VLAN
vlan make access-port et.6.1 stackable-vlan
! Add ports to VLANs
vlan add ports et.6.1 to BLUE
vlan add ports et.6.1 to GREEN
vlan add ports et.6.1 to PINK
vlan add ports et.6.1 to PURPLE
vlan add ports et.6.1 to AQUA
! Add port to backbone VLAN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
```

5.12.3 Displaying Stackable VLAN Information

Use the **vlan show stackable-vlan** command to display the configuration of stackable VLANs on the RS. For example:

```
rs# vlan show stackable-vlan
Stackable VLAN Information
==========================

(20, 222): ❶
   Applied On: et.6.1 ❷
   Flooded On: et.3.8,et.6.1 ❸

Stackable VLAN Trunk Ports: et.3.8 ❹

Stackable VLAN Access Ports: ❺
```


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The following explains the display:

1. The ID number of the VLAN, followed by the ID number of the backbone VLAN.
2. The tunnel entry/exit ports, configured with the **`vlan enable stackable-vlan`** command.
3. The ports on which multicast, broadcast, or unknown unicast packets are flooded.
4. The tunnel backbone ports, configured with the **`stackable-vlan`** option of the **`vlan make trunk-port`** command.
5. Tunnel entry ports that have also been configured (with the **`stackable-vlan`** option of the **`vlan make access-port`** command) as access ports that can belong to more than one VLAN of the same protocol type. This allows multiple VLANs to use the same tunnel entry port.

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6 SMARTTRUNK CONFIGURATION GUIDE

This chapter explains how to configure SmartTRUNKs on the RS. A SmartTRUNK is Riverstone's technology for load balancing and load sharing across a number of ports. SmartTRUNKs are used for building high-performance, high-bandwidth links between Riverstone's switching platforms. A SmartTRUNK is a group of two or more physical ports that have been combined into a single logical port. Multiple physical connections between devices are aggregated into a single, logical, high-speed path that acts as a single link. As flows are set up on the SmartTRUNK, traffic is balanced across all ports in the combined link, balancing overall available bandwidth.

SmartTRUNKs can also interoperate with switches, routers, and servers from other vendors. SmartTRUNKs allow administrators the ability to increase bandwidth at congestion points in the network, eliminating potential traffic bottlenecks. SmartTRUNKs also provide improved data link resiliency – if one link in a SmartTRUNK fails, its flows are distributed among the remaining links.

Note For detailed descriptions of the SmartTRUNK commands, see the "SmartTRUNK commands" section of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

SmartTRUNKs are compatible with all RS features, including VLANs, STP, VRRP, and so on. SmartTRUNK operation is supported over different media types and a variety of technologies including 10/100 Mbps Ethernet, Gigabit Ethernet, and Packet over Sonet (PoS).

6.1 CONFIGURING SMARTTRUNKS

Steps for creating and configuring a SmartTRUNK:

1. Create a SmartTRUNK and specify its control protocol.
2. Add physical ports to the SmartTRUNK.
3. Specify the policy for how flows are allocated on the SmartTRUNK's ports. This step is optional, and two flow set up policies are supported:
   - Round-robin – Flows are set up on ports sequentially.
   - Link-utilization – A new flow is established on the port that is currently the least utilized (the default).

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4. Specify whether the SmartTRUNK uses SmartTRUNK Load Redistribution (SLR). This step is optional. SLR allows the SmartTRUNK to dynamically move flows from port-to-port to take the best advantage of each link's current bandwidth.

6.1.1 Creating a SmartTRUNK

When creating a SmartTRUNK, assign a name to the SmartTRUNK and then select its control protocol. The choices for control protocol are: DEC Hunt Group control protocol, Link Aggregation Control Protocol (LACP), or no control protocol:

DEC Hunt Group – Can be used to connect a SmartTRUNK to another RS, Cabletron devices (such as the SmartSwitch 6000 or SmartSwitch 9000), or Digital GIGAswitch/Router. The Hunt Group protocol is useful for detecting errors like transmit/receive failures and misconfiguration.

LACP – If you are configuring the SmartTRUNK for 802.3ad link aggregation, specify the Link Aggregation Control protocol (LACP). LACP is limited to SmartTRUNKs comprised of Ethernet ports only, and all ports within the SmartTRUNK must have the same bandwidth, i.e., either all 10/100 Mbps Ethernet ports or all Gigabit Ethernet ports.

No Control Protocol – Can be used to connect the SmartTRUNK to another RS. Also, if you are connecting the SmartTRUNK to a device that does not support either DEC Hunt Group or LACP control protocols, such as those that support Cisco's EtherChannel technology, specify no control protocol. Only link failures are detected in this mode.

Here is an example of creating a SmartTRUNK named **st.1**, which uses no control protocol:

```
rs(config)#smarttrunk create st.1 protocol no-protocol
```

6.1.2 Adding Physical Ports to the SmartTRUNK

You can add any number of 10/100 Ethernet, Gigabit Ethernet, or PoS ports to a SmartTRUNK, and ports can span across any number of line cards. If one link should go down, traffic is redirected seamlessly to the remaining operational links.

SmartTRUNK Port Limitations

Ports added to a SmartTRUNK must meet the following criteria:

- Running in full duplex mode
- Be a member of the default VLAN
- If using LACP as the control protocol, ports must be all Ethernet and their bandwidth must be the same (either all 10/100 Mbps Ethernet or Gigabit Ethernet, but not both).

Here is an example of adding ports **et.3.1** through **et.3.8** to a SmartTRUNK:

```
rs(config)#smarttrunk add ports et.3.1-8 to st.1
```


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6.1.3 Specifying Traffic Load Policy

The default policy for assigning flows on the ports of a SmartTRUNK is “link-utilization,” where flows are assigned to the least-used ports in the SmartTRUNK. The other policy for assigning flows to ports is “round-robin,” where flows are assigned to ports on a sequential basis.

The traffic distribution policy only affects the initial assignment of L2 and L3 flows to a given port. If a link in the SmartTRUNK goes down, the flows are remapped to a different port in the same SmartTRUNK. If the flows assigned to a particular port in the SmartTRUNK exceed the bandwidth of the port, packets are dropped even if there is bandwidth available on other ports in the SmartTRUNK, unless SmartTRUNK Load Redistribution (SLR) is used. See Section 6.4, *"SmartTRUNK Load Redistribution"* for information about configuring SLR.

6.2 SMARTTRUNK EXAMPLE CONFIGURATION

Figure 6-1 shows a network design based on SmartTRUNKs. R1 is an RS operating as a router, while R2 and R3 are RSs operating as switches.

Timesaver To view the configuration of any device in the example below, click on that device’s image.

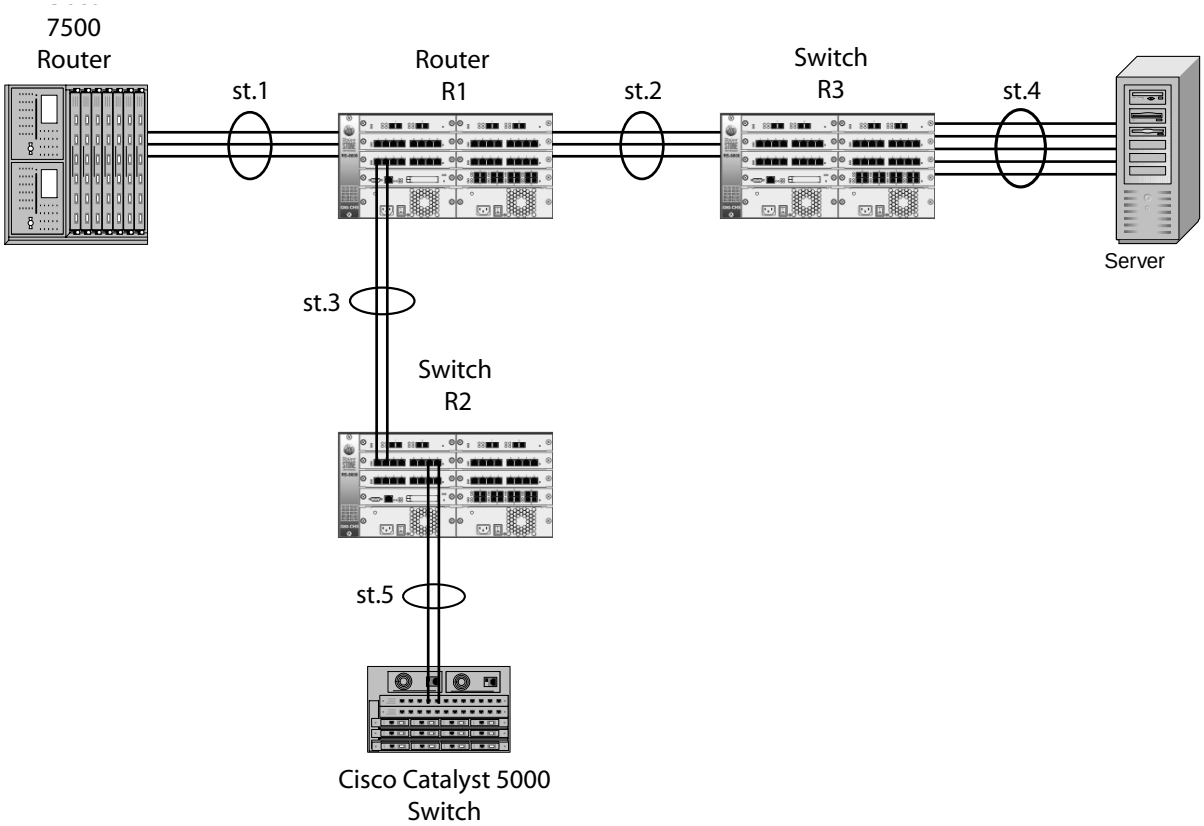

Figure 6-1 SmartTRUNK configuration example

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The following is the configuration for the Cisco 7500 router:

```
interface port-channel 1
ip address 10.1.1.1 255.255.255.0
ip route-cache distributed
interface fasteth 0/0
no ip address
channel-group 1
```

The following is the configuration for the Cisco Catalyst 5000 switch:

```
set port channel 3/1-2 on
```

The following is the SmartTRUNK configuration for the RS labeled ‘R1’ in the diagram:

```
smarttrunk create st.1 protocol no-protocol
smarttrunk create st.2 protocol huntgroup
smarttrunk create st.3 protocol huntgroup
smarttrunk add ports et.1(1-2) to st.1
smarttrunk add ports et.2(1-2) to st.2
smarttrunk add ports et.3(1-2) to st.3
interface create ip to-cisco address-netmask 10.1.1.2/24 port st.1
interface create ip to-s1 address-netmask 11.1.1.2/24 port st.2
interface create ip to-s2 address-netmask 12.1.1.2/24 port st.3
```

The following is the SmartTRUNK configuration for the RS labeled ‘R3’ in the diagram:

```
smarttrunk create st.2 protocol huntgroup
smarttrunk create st.4 protocol no-protocol
smarttrunk add ports et.1(1-2) to st.2
smarttrunk add ports et.2(1-2) to st.4
```

The following is the SmartTRUNK configuration for the RS labeled ‘R2’ in the diagram:

```
smarttrunk create st.3 protocol huntgroup
smarttrunk create st.5 protocol no-protocol
smarttrunk add ports et.1(1-2) to st.3
smarttrunk add ports et.2(1-2) to st.5
```

Note Notice in the example above that because R1 and R2 are operating only as switches (layer-2 traffic only), their SmartTRUNKs were not assigned to interfaces.

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6.3 CONFIGURING THE LINK AGGREGATION CONTROL PROTOCOL (LACP)

You can configure Riverstone's SmartTRUNK to support the 802.3ad Link Aggregation Control Protocol (LACP). When you do so, the SmartTRUNK is treated as the aggregator. As an aggregator, the SmartTRUNK presents a standard IEEE 802.3 service interface and communicates with the MAC client. The aggregator binds to one or more ports, is responsible for distributing frames from a MAC client to its attached ports, and for collecting received frames from the ports and passing them to the MAC client transparently.

You can enable LACP on all 10/100 Ethernet and Gigabit Ethernet ports on the RS. LACP ports exchange LACP PDUs with their peers and form one or more Link Aggregation Groups (LAGs). After joining a LAG, the port attaches to an appropriate aggregator (SmartTRUNK). However, for a port to attach to an aggregator, the following parameters must match between the port and the aggregator:

- Port's **`port-key`** must equal the aggregator's **`actor-key`**
- aggregator's **`partner-key`** must equal the port's **`partner-key`**
- aggregator's **`port-type`** must equal the port's **`port-type`** (10/100 or Gigabit Ethernet)
- aggregator's **`aggregation`** must equal the port's **`aggregation`** (**`aggregatable`** or **`individual`**)
- If specified by the user, the aggregator's **`partner-system-priority`** and **`partner-system-id`** (MAC) must equal the port's **`partner-system-priority`** and **`partner-system-id`** (MAC).

Note All ports on which LACP is enabled are devoted solely to LACP. All ports controlled by any aggregator must have the same bandwidth.

6.3.1 Configuring SmartTRUNKs for LACP

Note For a complete description of all parameters associated with the following LACP commands, see the *Riverstone Networks Command Line Interface Reference Manual.*

1. Create a SmartTRUNK and specify the LACP control protocol.:

```
rs(config)#smarttrunk create st.1 protocol LACP
```

2. Enable the LACP protocol on the SmartTRUNK's ports and specify a port key number using the **`lacp set port`** command. Here is an example:

```
rs(config)#lacp set port gi.1.1,gi.2.1 enable port-key 10
```


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Configure the aggregator's (SmartTRUNK's) LACP properties using the **`lacp set aggregator`** command. Here is an example:

```
rs(config)#lacp set aggregator st.1 port-type gigabit-Ethernet actor-key 10
partner-key 20
```

Note that the following parameters must be specified when using the **`lacp set aggregator`** command:

`port-type` – Specifies whether the ports associated with the aggregator are 10/100 Ethernet ports or Gigabit Ethernet ports.

`actor-key` – Specifies the administrative key of the aggregator.

`partner-key` – Specifies the administrative key of its partner system.

6.3.2 LACP Configuration Example

Consider the following full-mesh topology: Each RS is connected to the other RSs by aggregators. For the sake of simplicity, each Link Aggregation Group (LAG) consists of just two links. Each link consists of either 10/100 Ethernet or Gigabit Ethernet. Notice the LACP restriction that each LAG must contain links of identical bandwidth only (either all 10/100 Ethernet or Gigabit Ethernet, but not both).

Timesaver To view the configuration of any of the RSs in the example below, click on that switch's image.

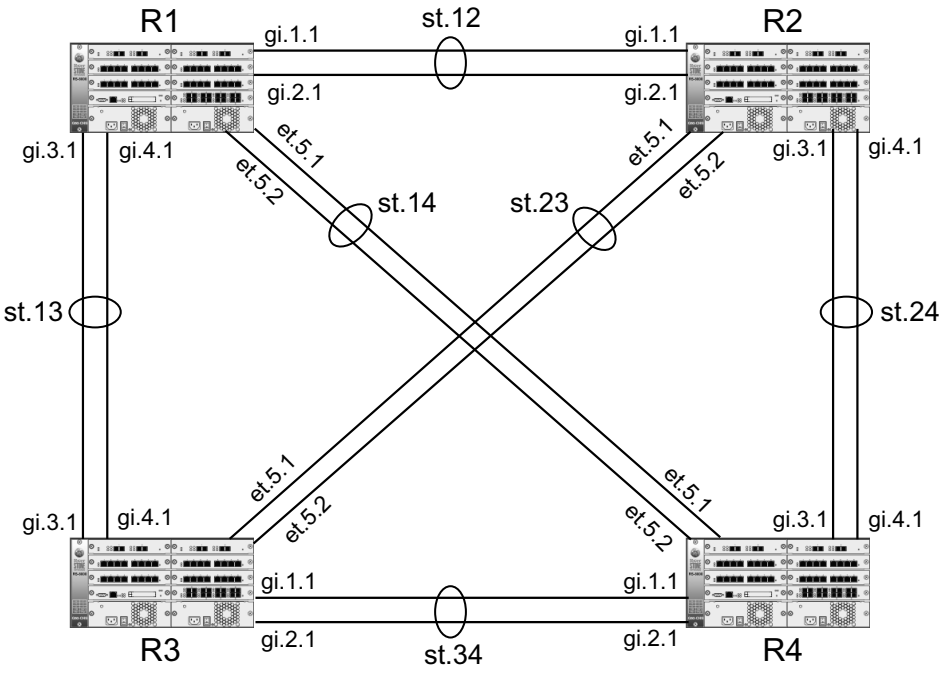

Figure 6-2 LACP configuration example

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R1, R2, R3, and R4 are connected by aggregators (SmartTRUNKs) **st.12**, **st13**, **st.14**, **st.23**, **st.24**, and **st.34**. Notice that **st.12**, **st.13**, **st.24**, and **st.34** consist of Gigabit Ethernet links, while **st.14** and **st.23** consist of 10/100 Ethernet links. Table 6-1 shows the relationship between the aggregators, the RS switches, and the ports contained within the LAGs that bind to their respective aggregator.

Table 6-1 Aggregator – RS – port relationship

AGGREGATOR	RS SWITCHES	PORTS
st.12	R1	gi.1.1, gi.1.2
	R2	gi.1.1, gi.1.2
st.13	R1	gi.3.1, gi.4.1
	R3	gi.3.1, gi.4.1
st.14	R1	et.5.1, et.5.2
	R4	et.5.1, et.5.2
st.23	R2	et.5.1, et.5.2
	R3	et.5.1, et.5.2
st.24	R2	gi.3.1, gi.4.1
	R4	gi.3.1, gi.4.1
st.34	R3	gi.1.1, gi.1.2
	R4	gi.1.1, gi.1.2

Configuration for R1:

```
smarttrunk create st.12 protocol lacp
smarttrunk create st.13 protocol lacp
smarttrunk create st.14 protocol lacp
lacp set aggregator st.12 port-type gigabit-Ethernet actor-key 10 partner-key 20
lacp set aggregator st.13 port-type gigabit-Ethernet actor-key 10 partner-key 30
lacp set aggregator st.14 port-type 10-100-Ethernet actor-key 11 partner-key 41
lacp set port gi.1.1,gi.2.1 enable port-key 10
lacp set port gi.3.1,gi.4.1 enable port-key 10
lacp set port et.5.1,et.5.2 enable port-key 11
stp set protocol-version rstp
stp enable port st.(12,13,14)
```


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Configuration for R2:

```
smarttrunk create st.12 protocol lacp
smarttrunk create st.23 protocol lacp
smarttrunk create st.24 protocol lacp
lacp set aggregator st.12 port-type gigabit-Ethernet actor-key 20 partner-key 10
lacp set aggregator st.23 port-type 10-100-Ethernet actor-key 21 partner-key 31
lacp set aggregator st.24 port-type gigabit-Ethernet actor-key 20 partner-key 40
lacp set port gi.1.1,gi.2.1 enable port-key 20
lacp set port gi.3.1,gi.4.1 enable port-key 20
lacp set port et.5.1,et.5.2 enable port-key 21
stp set protocol-version rstp
stp enable port st.(12,23,24)
```

Configuration for R3:

```
smarttrunk create st.13 protocol lacp
smarttrunk create st.23 protocol lacp
smarttrunk create st.34 protocol lacp
lacp set aggregator st.13 port-type gigabit-Ethernet actor-key 30 partner-key 10
lacp set aggregator st.23 port-type 10-100-Ethernet actor-key 31 partner-key 21
lacp set aggregator st.34 port-type gigabit-Ethernet actor-key 30 partner-key 40
lacp set port gi.1.1,gi.2.1 enable port-key 30
lacp set port gi.3.1,gi.4.1 enable port-key 30
lacp set port et.5.1,et.5.2 enable port-key 31
stp set protocol-version rstp
stp enable port st.(13,23,34)
```

Configuration for R4:

```
smarttrunk create st.14 protocol lacp
smarttrunk create st.24 protocol lacp
smarttrunk create st.34 protocol lacp
lacp set aggregator st.14 port-type 10-100-Ethernet actor-key 41 partner-key 11
lacp set aggregator st.24 port-type gigabit-Ethernet actor-key 40 partner-key 20
lacp set aggregator st.34 port-type gigabit-Ethernet actor-key 40 partner-key 30
lacp set port gi.1.1,gi.2.1 enable port-key 40
lacp set port gi.3.1,gi.4.1 enable port-key 40
lacp set port et.5.1,et.5.2 enable port-key 41
stp set protocol-version rstp
stp enable port st.(14,24,34)
```

Note Notice that the **partner-key** specified in each configuration is the **port-key** of the corresponding ports on the RS at the other end of the SmartTRUNK.

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6.4 SMARTTRUNK LOAD REDISTRIBUTION

SmartTRUNK Load Redistribution (SLR) monitors all ports within a SmartTRUNK for utilization. If a port begins to become overloaded, SLR automatically moves some of the port's flows to other, less utilized ports within the SmartTRUNK. SLR is enabled for the entire SmartTRUNK, and can be used in unison with any control protocol or load policy (see Section 6.1.3, *"Specifying Traffic Load Policy"* and Section 6.3.1, *"Configuring SmartTRUNKs for LACP"*).

Note When a SmartTRUNK is created, one of the ports is elected for sending and receiving layer-2 multicast and broadcast traffic. SLR leaves these layer-2 multicast or broadcast flows unaffected.

Note Each time a redistribution is performed by SLR, an SNMP trap is generated.

6.4.1 SLR Water-marks

SLR uses "water-marks," based on percentage port utilization, to determine whether flows on a port need to be redistributed to other ports within the SmartTRUNK.

SLR uses the three following user-defined water-marks:

- Low water-mark (**lwm**) – Used by SLR to detect whether a port is under utilized; the default is 20% of bandwidth
- Medium water-mark (**mwm**) – Used by SLR as a baseline of normal port utilization; the default is 50% of bandwidth
- High water-mark (**hwm**) – Used by SLR to detect whether a port is over utilized; the default is 80% of bandwidth

Note Water-marks are set on a per-SmartTRUNK basis, i.e., water-marks cannot be set on a per-port basis.

6.4.2 Polling intervals

SLR uses two intervals to perform load redistribution:

Status Interval – Interval in which port utilization information is gathered; the default is one second.

Redistribution Interval – Interval in which SLR considers flows for redistribution. The Redistribution Interval is the number of Status Intervals that must pass before flows are considered for redistribution.The Redistribution Interval relates to a number of Status Intervals, as opposed to being a measure of time; the default is 5 Status Intervals.

To determine the length of time in seconds for one Redistribution Interval, multiply the Status Interval by the Redistribution Interval value. For example, using the defaults,

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Status Interval = 1 second

Redistribution Interval = 5 Status Intervals

then

1 * 5 = 5 seconds per Redistribution Interval.

Note To avoid flows "bouncing" back and forth between ports, SLR uses the rule that no moved flow can be returned to the port from which it was moved until at least one Redistribution Interval has passed.

Creating an SLR Enabled SmartTRUNK

The following is an example of creating a SmartTRUNK that uses SLR:

1. Create a SmartTRUNK (**st.4**) — the control protocol is irrelevant to this example:

```
rs(config)# smarttrunk create st.4 protocol no-protocol
```

2. Assign ports **et.4.1** through **et.4.4** to the SmartTRUNK:

```
rs(config)# smarttrunk add ports et.4.1-4 to st.4
```

3. Accept SLR's defaults and enable SLR on the SmartTRUNK.

```
rs(config)# smarttrunk set load-redistribution-params st.4 enable
```

To show the SmartTRUNK SLR configuration on **st.4**, enter the following command from Enable mode:

```
rs# smarttrunk show load-redistribution-params st.4 configuration

   st.4 configuration:
        Intervals (in seconds):
            Stats Interval           1 seconds
            Redistribute Interval    5 Stats Intervals
        Port Watermarks:
            HWM                      80%
            MWM                      50%
            LWM                      20%
        Options:
            Verbose                  False
            Redistribute L2 Flows    True
            Redistribute IP Flows    False
            Ignore LWM Event         True
            Stats Discard            3 Stats Intervals
            Max Flow Search Attempts 100
```


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To monitor SmartTRUNK SLR activity on **st.4**, enter the following command from Enable mode:

```
rs# smarttrunk show load-redistribution-params st.4 statistics

    st.4        Link     Moving Avg   Over     Above    Above    Below    Below     Port
    Output  Utilization     Load     Capacity   HWM      MWM      MWM      LWM    Capacity
    Ports    %capacity   %capacity  History  History  History  History  History    Mb/s
   -------- ----------- ----------- -------- -------- -------- -------- -------- ---------
   et.4.1      38.46       38.46          0        0        0      306        0      100
   et.4.2      57.70       57.70          0        0      304        0        0      100
   et.4.3      57.70       57.69          0        0      198        0        0      100
   et.4.4      76.92       76.92          0        0      198        0        0      100

   st.4: 1 redistributions in the last 0 Hr, 10 Min, 10 Sec
rs#
```

Notice that **statistics** displays the following values on a per-port basis:

- port name
- port capacity in bandwidth
- link utilization and its exponential moving average
- instances when water-marks have been exceeded

Also note that **statistics** reports how many flows have been redistributed since they were last cleared.

To see only a summary of the redistribution activities, enter smarttrunk **show load-redistribution-params st.4 summary** while in Enable mode.

To clear the SLR statistics, use the following command in Enable mode:

```
rs# smarttrunk clear load-distribution st.4
```

6.4.3 Additional Controls Provided by SLR

SmartTRUNK Load Redistribution is primarily intended for use where large numbers of layer-2 flows are deployed to carry traffic transparently. In this environment, SLR provides automatic load-balancing of flows on SmartTRUNKs consisting of any number of ports. However, the smarttrunk **set load-redistribution-params** command provides a number of parameters for enabling and tuning the behavior of SLR. The following sections describe two of these parameters.

Note For a detailed description of all the **load-redistribution-params** parameters, see the SmartTRUNK section in the *Riverstone Network RS Switch Router Command Line Interface Reference Manual.*

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Redistribution of IP Flows

The **smarttrunk set load-redistribution-params** command is used to specify the redistribution of layer-3 flows by setting the **ip-redistribute** parameter. For example:

```
rs(config)#smarttrunk set load-redistribution-params st.4 redistribute-ip
```

Layer-3 flows, as well as layer-2 flows, will now be affected by SLR on SmartTRUNK **st.4**.

Typically, IP (layer-3) flows are short-lived compared to layer-2 flows. For example, a customer decides to surf the web. As the customer moves from site to site, layer-3 flows are established and then torn down. Depending on the amount of time the customer spends at each site, these layer-3 flows could be fairly short-lived. In this case, it would be a waste of switch resources to redistribute these flows along with the layer-2 flows. On the other hand, if you provide a service that requires long-lived layer-3 flows (for example, streaming video), you may want to consider including Layer-3 flows for redistribution.

Using Low Water-Mark Events

A low water-mark event occurs than traffic on a SmartTRUNK port falls below the low water-mark threshold. By default, SLR ignores low water-mark events. However, low water mark events can help SLR to determine whether a port is being under utilized. If a port experiences many low water mark events, SLR will attempt to even out traffic across the SmartTRUNK by redistributing flows to the under utilized port.

The **smarttrunk set load-redistribution-params** command is used to specify the use of low water-mark events by setting the **dont-ignore-lwm-events** parameter. For example:

```
rs(config)#smarttrunk set load-redistribution-params st.4 dont-ignore-lwm-events
```

However, using low water-mark events with SmartTRUNKs that contain ports of widely varying bandwidth can cause problems. This is why low water-mark events are disabled by default. To understand why using low water-mark events can be an issue, consider the following scenario:

- A SmartTRUNK consists of five 100 Megabit Ethernet ports and one Gigabit Ethernet port, and **dont-ignore-lwm-events** is specified.
- By default, the low water-mark is set at 20%. This means that on the 100 Megabit ports 20% of bandwidth is 20 Megabits/sec, while on the Gigabit Ethernet port, 20% of bandwidth is 200 Megabits/sec.
- The large bandwidth of the Gigabit Ethernet port causes it to trigger many low water-mark events, which indicate to SLR that the Gigabit Ethernet link is vastly under utilized. As a result, most flows are moved to the Gigabit Ethernet port, while the remaining links go under utilized.

The best use for low water-mark events is with SmartTRUNKs that are made up of links that have equal bandwidth. In such configurations, low water-mark events combine with high water-mark events to increase the efficiency of SLR's redistribution process.

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7 CMTS CONFIGURATION GUIDE

This chapter describes how to connect and configure Riverstone's Cable Modem Termination System (CMTS). The CMTS interface is an RS 8000/8600 series module that supports one transmit (downstream) and four receive (upstream) ports. The RS 8000/8600 chassis with the CMTS module provides wire-speed CMTS integration.

Riverstone offers an integrated CMTS that is DOCSIS and EuroDOCSIS compliant, enabling cable MSOs to provide data transmission over a two-way cable TV (HFC) infrastructure.

7.1 HFC CABLE NETWORK ARCHITECTURE

The architecture of a two-way hybrid fiber coaxial (HFC) network is based on the traditional one-way HFC-cable network. The headend is the cable distribution center. The traditional HFC cable headend provides the broadcast of television channels. These channels are comprised of input signals such as off-air channels, satellite channels, local community programming, and local advertisement insertion. With the Riverstone CMTS module and an intermediate frequency (IF) to-radio frequency (RF) upconverter installed at the headend, digital data can be transmitted over the same infrastructure as the traditional television channels. The Riverstone CMTS downstream ports transmit IF signals to the upconverter, which translates the signals to RF. The translated signal are then processed for distribution with the television signals.

Receivers, scamblers, and descramblers process the television signals to encode or decode them as needed for broadcast. Modulators format the television and digital signals.

The analog and digital signals then pass through the RF combiner (cables, amplifiers, and taps the headend) and are broadcast from the headend through the optical transmitters to optical fiber nodes in the network. Amplifiers, coaxial cable, and taps carry the signals to the subscriber's premises. The analog signals are received by cable set top boxes, televisions, and VCRs as they are in one-way HFC networks. Digital signals are received by cable modems that are connected to the subscribers computers via 10BaseT Ethernet cables.

On the upstream path, the cable modems transmit RF signals back through additional amplifiers to optical fiber receivers at the headend. These receivers pass the upstream signal to the upstream ports on the Riverstone CMTS where they are processed. For example, the upstream signal might be a request to access a worldwide web page on the Internet.

7.2 CMTS MODULE DESCRIPTION

The front panel of the CMTS module shown in Figure 7-1 has five connectors. Connectors US 1 through US 4 are for connecting the upstream inputs. The connector labeled IF DS is for connecting the downstream output. LEDs located on the front panel operate in a LAN centric manner. The green LED indicates that a link is established and a yellow LED indicates that a packet is being transmitted or received.

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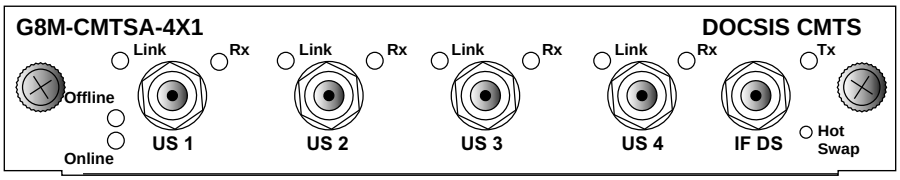

Figure 7-1 CMTS Module Front Panel

By default the upstream channels are disabled. Use the command line interface to enable the upstream channels before use. The channels are identified in the CMTS configuration based on the slot the CMTS module occupies in the RS 8000/8600 chassis and the location of the connector on the front panel.

Only those commands that operate on a specific upstream channel (or group of channels) require that the channel be specified.

To enable upstream channel 1 on a CMTS module located in slot 7 of the RS 8000/8600 chassis you would enter the following command:

```
cmts set uschannel cm.7.1 upstream 1 state on
```

When setting the upstream channel, modulation profile 1 is assigned by default. Three predefined profiles are available – 1, 2, and 3. These profiles may be modified. In addition, you can create up to five additional profiles for use in your installation.

For more information about the physical characteristics of the CMTS module and for installation instructions in the RS 8000/8600 chassis refer to *Riverstone RS Switch Router Getting Started Guide*.

7.3 PROVISIONING THE HEADEND

Prior to installing the RS 8000/8600 with CMTS the headend must be prepared for two-way data operation. For this preparation the cable headend should be:

- Swept, balanced, and certified for analog and two-way data.
- Wired for narrowcast downstream data transmission.
- Wired to supply an RF feed from the upstream fiber-optic receivers to the CMTS

In addition, the following should be accomplished:

- Upstream frequencies allocated for data transmission.
- Upstream ingress noise measured and understood.
- Downstream frequencies assigned.
- All RF connectivity verified.

When the RS 8000/8600 is installed:

- Internet connectivity should be established (if internet connectivity is required).
- Internet addresses must be obtained and allocated.
- The DHCP, TFTP, DNS and TOD servers must be configured and enabled.

The following sections describe connecting and configuring the RS 8000/8600 CMTS.

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7.3.1 Headend Certification

The cable headend plant must pass both analog and digital certification. In the United States, analog certification is an annual measurement procedure mandated by the Federal Communications Commission. Consult with local agencies for local analog certification requirements.

7.3.2 IF-RF-Upconverter

The downstream output of the CMTS module is 44 MHz IF (intermediate frequency). To be compatible with cable television system frequency division multiplexing, you must install an external IF-to-RF upconverter that translates the IF signal to RF carrier frequency. The upconverter also allows you to maintain your existing channel lineup.

Upconverters are available from many manufacturers and can be found in configurations ranging from a fixed number of ports to flexible multislot, multiport models. You must install and configure enough upconverter ports to support the number for downstream CMTS line cards installed in each RS 8000/8600. The number of upconverter units you will need to purchase depends on the manufacturers. The upconverters you use in your installation must support 64 and 256 QAM digital signals

An analog channel modulator with external IF-loops is not suitable for use as a digital QAM upconverter. These units typically do not have the phase noise performance levels required for 64 and 256 QAM digital signals, and they might cause lower performance and possible system failure.

The upconverter is installed between the CMTS and the combiner as shown in Figure 7-2. The combiner refers to all the cables, amplifiers, and taps at the headend or cable distribution center that connect the CMTS to the hybrid fiber coaxial network.

7.3.3 Diplex Filters

A diplex filter must be installed in the RF path between the CMTS modules in the RS 8000/8600 chassis and the cable modems. Diplex filters are used to separate the high-band frequency downstream signals from the low-band frequency upstream signals. High-band signals flow in the downstream direction from the RS 8000/8600 to the cable modems, and low-band signals flow in the upstream direction from the cable models to the RS 8000/8600.

A simple example is when the input of the diplex filter consists of three ports: the high filter port, the low filter port, and the common port. The common port (the output) is connected to a splitter. Unused connection ports on the splitter must be terminated.

The downstream output signal from the RS 8000/8600 runs through the upconverter, and then enters the high filter port on the diplex filter. The signal exits the common port on the filter and is distributed to the cable modems. The upstream signal from the cable modems enters the common port of the diplex filter and flows to the upstream receiver ports on the RS 8000/8600 CMTS modules through the low filter port.

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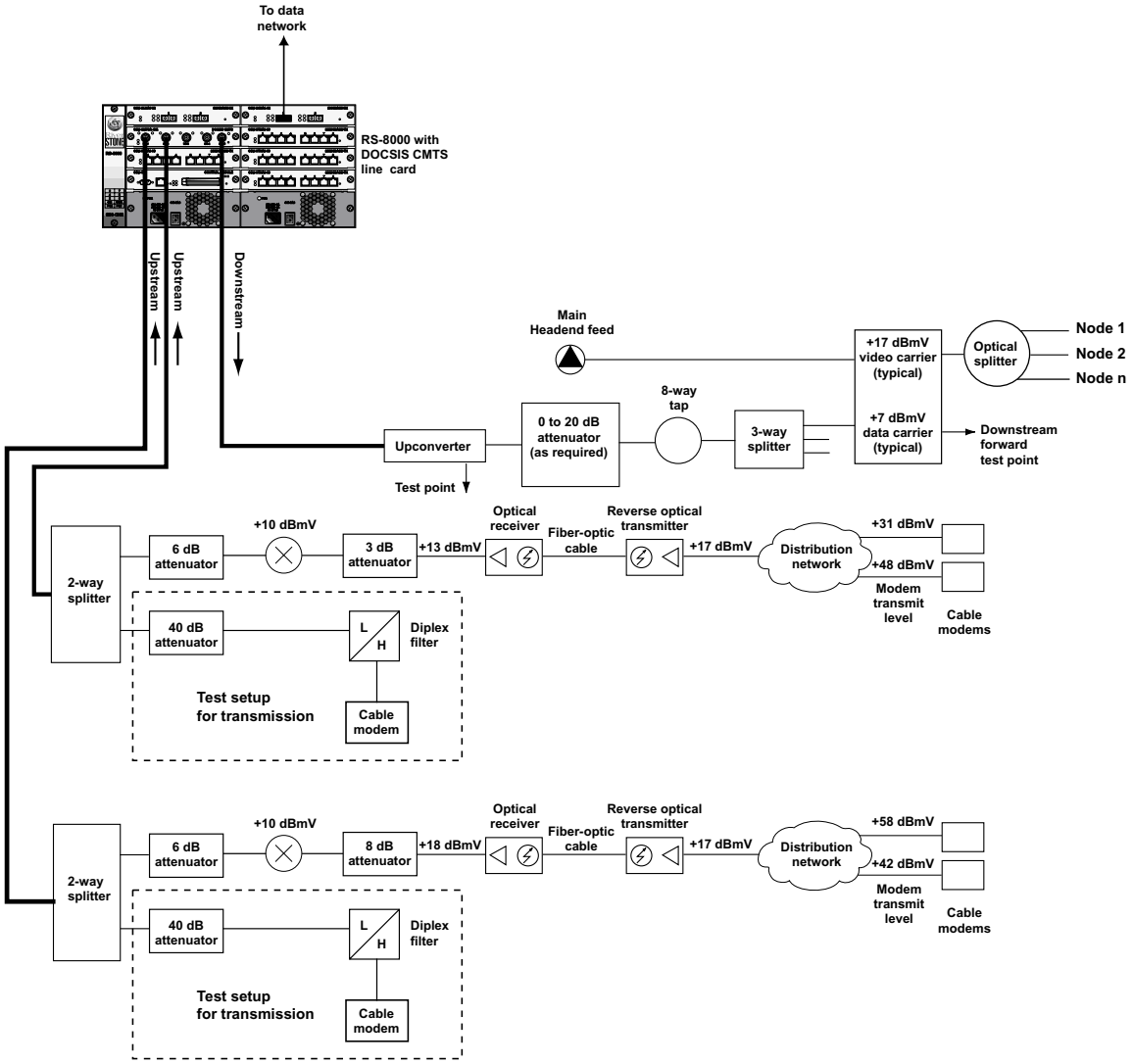

Figure 7-2 CMTS Connection Overview

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7.3.4 DHCP Servers

A Dynamic Host Configuration Protocol (DHCP) server must be installed at the headend site to assign an IP address to each cable modem in compliance with DOCSIS specification. The DHCP server must also offer a time-of-day server option that is compliant with RFC-868.

Note In HFC networks where a small number of cable modems are installed, the DHCP/TFTP server can be installed somewhere on the wide-area network (WAN) instead of at the headend. In a routed configuration, the RS 8000/8600 can be configured as a proxy device to forward DHCP requests from cable modems to the DHCP server.

The CMTS module uses these assigned IP addresses to identify individual cable modems operating on the network. The CMTS module stores DOCSIS registration parameters for future reference.

Note The RS 8000/8600 DHCP server should not be used.

When a DHCP server is configured in a network, the server assigns an IP address to each cable modem when a connection is made to the network. The RS 8000/8600 periodically polls the cable modems on the network to see if the network connection is still active. When the connection to the network ends, the IP address is reassigned, as needed, to other cable modems establishing a connection to the network.

If a cable modem's IP address assignment expires and the DHCP server is not accessible, the cable modem will not operate as a bridge to other network devices until another IP address is obtained. When a cable modem enters ranging and registration mode to obtain another IP address, the RS 8000/8600 will not handle any requests to or from other devices attached to the cable modem.

7.3.5 DNS and TFTP Servers

In conjunction with the DHCP server, a Domain Name Server (DNS) server must be installed to translate names of network nodes into IP addresses, and a Trivial File Transfer Protocol (TFTP) server must be installed to transfer configuration files over the network for field support and future software upgrades.

7.4 CONNECTING AND CONFIGURING THE DOWNSTREAM

After installing the RS 8000/8600 router chassis and the CMTS module at the headend site, connect the CMTS module to the HFC network and configure the network. The following sections describe how to connect to and configure the downstream.

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7.4.1 Installing and Configuring the Upconverter

If you have not already done so, unpack the IF-to-RF upconverter at your headend site and install it near your RS 8000/8600 router. If your router is installed in a rack, install the upconverter in the same rack, if possible.

Note Refer to the user documentation that accompanied your upconverter for safety information and specific installation instructions.

7.4.2 Setting the Upconverter Input Level

Set the upconverter IF input level, according to the manufacturer's instructions, to match the output level of the cable modem cards. Riverstone CMTS modules feature on output rating of +30 dBmV (+/-2 dBmV).

Depending on the upconverter model selected you might need to add attenuation to the upconverter input to compensate for cable length in the headend, and for the design of the upconverter. For example, the IF input to the General Instrument C6U is +23 dBmV and this upconverter requires 6 to 19 dB of attenuation on the input cable. The IF input to the Wavecom MA4040 is +33 dBmV and requires no attenuation on the input cable.

7.4.3 Setting the Upconverter Output Level

Set the upconverter output RF level, according to the manufacturer's instructions. DOCSIS and EuroDOCSIS specifications permit an RF output level of +50 to +61 dBmV. Select an output level that falls within this range that is valid for your upconverter.

Note Never set the upconverter output level greater than +61 dBmV. DOCSIS-based cable modems will not be able to communicate with the headend if the upconverter output level is set too high. The signal will be distorted in overdrive state.

7.4.4 Setting the Upconverter Output Frequency

Select an output frequency. Both DOCSIS and EuroDOCSIS specifications permit channels from 91 to 857 MHz (center frequency).

Your output frequency should be in your *narrowcast* band of frequencies, or the narrowcast combiner. Narrowcast frequencies are defined as frequencies that are transmitted to certain groups of fiber nodes or regions in your network. The same programming content is received within each group of fiber nodes or regions. Different groups will receive different content.

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7.4.5 Completing the Downstream Configuration

To complete the downstream configuration, you must combine the upconverter output with the main headend broadcast feed into the laser transmitter in the headend. The narrowcast feed, which includes cable modem service and digital video and local access channels, is connected to the laser transmitter input using an 8-way tap and a 3-way splitter.

The 8-way tap has an insertion loss of 11 dB and the 3-way splitter has an insertion loss of 7 dB. The combined loss is 18 dB. With this combined insertion loss, you will overdrive the input on the transmitter and it will not work properly. In order to compensate for this insertion loss, you must add attenuation to the digital carrier laser input. The input level for the data carrier is +7 dBmV, or 10 dB below the analog carrier. In this example, start with a 20-dB attenuator to adjust for the insertion loss and passive loss in the headend cables.

If you have a very large, complex headend system with many outputs, you might notice a very large passive loss in your headend combining network. For example, in a very large headend with 100 feet of RG-59 or 59 series headend coaxial cable, you might see losses of 6 to 8 dB. To compensate for this loss, you can install the upconverter closer to the laser transmitters.

7.4.6 Testing the Downstream Configuration

To test the downstream configuration, you can connect a cable modem to the downstream forward test point of the laser transmitter. Use a diplex filter and an attenuator, as needed, to connect the cable modem to an upstream port on the RS 8000/8600 CMTS module.

The nominal input level for a RS 8000/8600 CMTS module upstream port is 0 dBmV, but it can also be adjusted as low as -16 dBmV or as high as +26 dBmV using RS 8000/8600 CMTS module software.

The RS 8000/8600 CMTS module will instruct the modem to adjust its output level to match the current input level. Your test cable modem will require a minimum of 8 to 10 dB of attenuation between the upstream of the cable modem and the upstream port on the RS 8000/8600 CMTS module.

If this configuration is working properly, you have a very good chance of getting the rest of the network up. If this configuration generates a low carrier-to-noise ratio (C/N) estimate in the cable modem, you need to make further adjustments.

You can measure the preliminary C/N ratio estimate at the headend downstream laser test point. This measurement can be used to verify the performance of the upconverter, headend combiner, and forward distribution system before cable modems are installed on the HFC network.

7.5 CONNECTING THE UPSTREAM TO THE LASER RECEIVER

To connect the upstream to the laser receiver, use a 2-way splitter as a combiner to leave the RS 8000/8600 CMTS module cable access router connected at the headend, and connect the upstream headend cable to the laser receiver.

You must adjust the upstream input level to the RS RS 8000/8600 CMTS line card so the output of the laser receiver is the same as the input to your upstream port or your RS 8000/8600 CMTS module.

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7.6 CONFIGURING THE CMTS MODULE

There are two ways to configure the CMTS module for operation, in a routed network and in a bridged network. In the bridged network the CMTS module and the DHCP server must be on the same VLAN. In the routed network, the DHCP server can be located on the routed network.

The procedure in this section assume that you have installed the operating software for the system, logged onto the system, and performed initial system configuration.

7.6.1 Configuring the CMTS Module in a Bridged Network

Before preforming the steps in this example procedure you must set up the DHCP server to assign IP addresses in a range that is compatible with the VLAN that the CMTS module and the DHCP server are assigned. Prior to performing this procedure you must also set up the TFTP and DNS servers.

VLANs are used to associate physical ports with connected hosts that need to participate in the same broadcast domain. To associate ports to a VLAN, you must first create a VLAN and then assign ports to the VLAN.

Configure the CMTS module by entering the following commands:

1. Create an IP VLAN. In this example the VLAN is named ‘dhcp.’ Create the VLAN by entering:

   `vlan create dhcp ip`

2. Assign the RS 8000/8600 Ethernet port to the VLAN named ‘dhcp’ by entering:

   `vlan add ports et.1.1 to dhcp`

3. Assign the CMTS port to the VLAN named ‘dhcp’ by entering:

   `vlan add ports cm.7.1 to dhcp`

4. Create an IP interface called ‘dhcp’ with the address 10.50.86.23 for the VLAN ‘dhcp’ by entering:

   `interface create ip dhcp address-netmask 10.50.86.23/16 vlan dhcp`

5. The **`system set name`** command configures the name of the RS 8000/8600. Name the system ‘CMTS3’ by entering:

   `system set name CMTS3`

6. The **`system set timezone`** command sets the local time zone. Set the time zone to Pacific Standard Time using the keyword ‘pst’ by entering:

   `system set timezone pst`

7. Establish the authorization text string for the CMTS module by entering:

   `cmts set headend cm.7.1 auth-str DOCSIS`

8. Enable the upstream channels are necessary. The following command enables upstream channel 1 by entering:

   `cmts set uschannel cm.7.1 upstream 1 state on`

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7.6.2 Configuring the CMTS Module in a Routed Network

The example procedure in this section shows configuring the CMTS to operate in a routed network. Before preforming the steps in this example procedure you must set up the DHCP server to assign IP addresses in a range that is compatible with the VLAN that the CMTS module and the DHCP server are assigned. Prior to performing this procedure you must also set up the TFTP and DNS servers.

1. The **vlan create** command creates a VLAN definition. In the following command a port-based VLAN is created. A port-based VLAN supports IP, SNA, DECnet, IPv6, Appletalk, SNA and Other protocols. To create a port-based VLAN definition, enter:

   ```
   vlan create cmts port-based
   ```

2. Create an IP VLAN. In this example the VLAN is named ‘dhcp.’ Create the VLAN by entering:

   ```
   vlan create dhcp ip
   ```

3. Assign the RS 8000/8600 Ethernet port to the VLAN named ‘dhcp’ by entering:

   ```
   vlan add ports et.1.1 to dhcp
   ```

4. Assign the CMTS port to the VLAN named ‘cmts’ by entering:

   ```
   vlan add ports cm.7.1 to cmts
   ```

5. Create an IP interface called ‘dhcp’ with the address 10.50.86.23 for the VLAN ‘dhcp’ by entering:

   ```
   interface create ip dhcp address-mask 10.50.86.23/16 vlan dhcp
   ```

6. Create an IP interface called ‘cmts’ with the address 50.3.1.1 for the VLAN ‘cmts’ by entering:

   ```
   interface create ip cmts address-netmask 50.3.1.1/16 vlan cmts
   ```

7. You can configure the RS 8000/8600 system to forward UDP broadcast packets received on a given interface to all other interface by entering.

   ```
   ip helper-address interface cmts all-interfaces
   ```

8. The **system set name** command configures the name of the RS 8000/8600. Name the system ‘CMTS3’ by entering:

   ```
   system set name CMTS3
   ```

9. The **system set timezone** command sets the local time zone. Set the time zone to Pacific Standard Time using the keyword ‘pst’ by entering:

   ```
   system set timezone pst
   ```

10. Establish the authorization text string for the CMTS module by entering:

    ```
    cmts set headend cm.7.1 auth-str DOCSIS
    ```

11. Enable the upstream by entering the following command:

    ```
    cmts set uschannel cm.7.1 upstream all state on
    ```


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7.7 CMTS CONFIGURATION EXAMPLES

The following section contains real-world configurations for broadband network layouts. Each example describes how to use the RS' CMTS capabilities to support multiple ISPs. For all examples, assume that there are two ISPs, AMERILINK and MOONLINK, each with two subscribers.

- AMERILINK
  - Ethernet Network: 50.1.0.0
  - RF Network: 50.2.0.0
  - Server: 50.1.1.100
- MOONLINK
  - Ethernet Network: 80.1.0.0
  - RF Network: 80.2.0.0
  - Server: 80.1.1.100

The configuration for the RS is as follows:

- Slot 1: 8 port 10/100 card
- Slot 5: CMTS card
- AMERILINK Eth interface: 50.1.1.1
- MOONLINK Eth interface: 80.1.1.1

Note The DHCP server software used in these examples is version 2 of the ISC DHCP Distribution. Please see http://www.isc.org for more details on this server.

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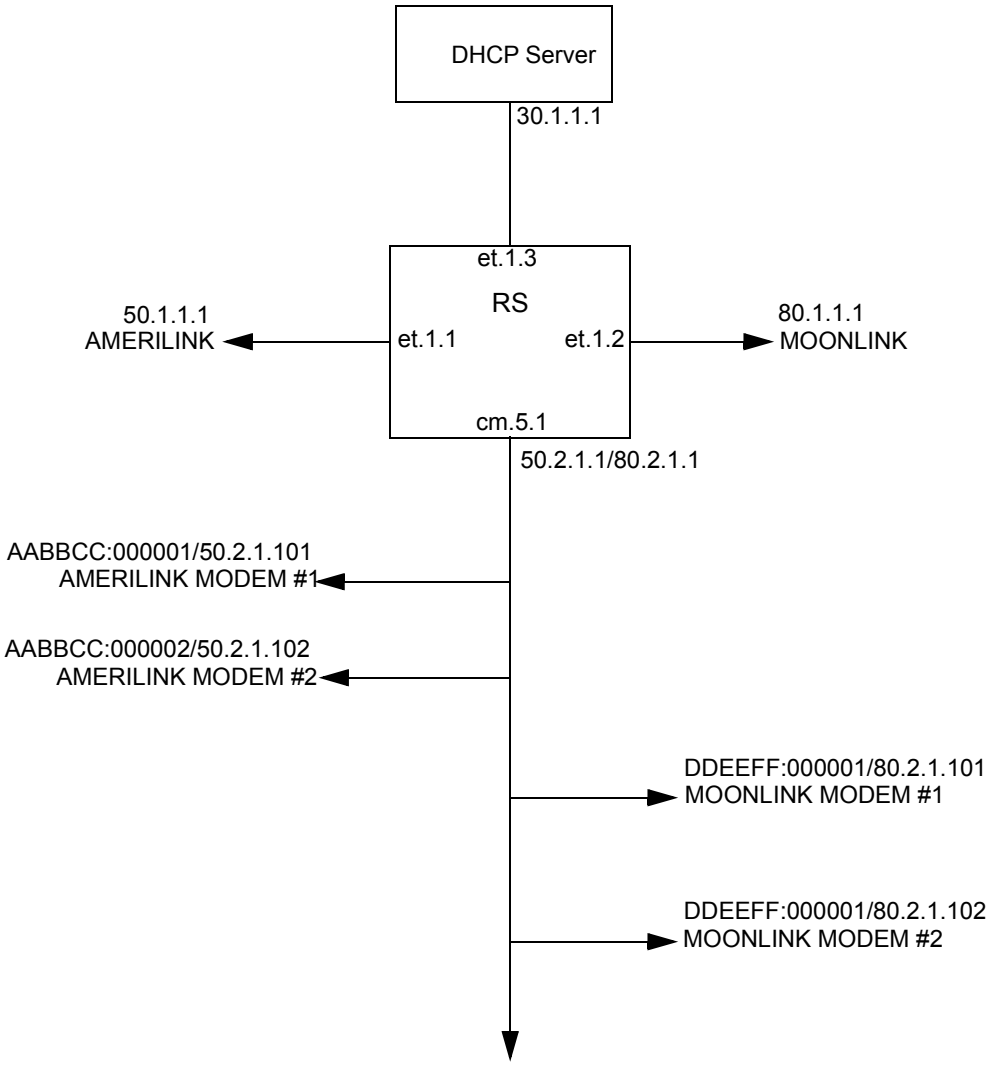
7.7.1 Example One: Multiple ISPs Share a Single DHCP Server

In this example, the DHCP server can be run on either the AMERILINK or MOONLINK network. The advantages of this type of configuration are that it is simple, there is only a single database, and the ISP selection is transparent to the user. The disadvantage is that the ISPs must share access to the DHCP server. They can, however, still manage their own TFTP and TOD servers.



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Following, is the configuration:

```
! Configure the RS
cmts set headend cm.5.1 auth-str DOCSIS
cmts set uschannel cm.5.1 upstream 1 state on
! Configure the VLANs
vlan create AMERILINK port-based
vlan create MOONLINK port-based
vlan create CMTS port-based
vlan create DHCP port-based
vlan add ports et.1.1 to AMERILINK
vlan add ports et.1.2 to MOONLINK
vlan add ports cm.5.1 to CMTS
vlan add ports et.1.3 to DHCP
interface create ip AMERILINK address-netmask 50.1.1.1/16 vlan
AMERILINK
interface create ip MOONLINK address-netmask 80.1.1.1/16 vlan MOONLINK
! The RF interface has overlapping subnets, one for AMERILINK and the other for
! MOONLINK
interface create ip CMTS address-netmask 50.2.1.1/16 vlan CMTS
interface add ip CMTS address-netmask 80.2.1.1/16
interface Create ip DHCP address-netmask 30.1.1.1/16 vlan DHCP
ip helper-address interface CMTS 30.1.1.100
```


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Following, is the configuration for the DHCP server:

```
# prevents unknown hosts from getting information from this dhcp server
deny unknown-clients;

# server requires a declaration for subnet directly attached
subnet 30.1.0.0 netmask 255.255.0.0 {
}
shared-network amerilink_moonlink {

# AMERILINK's network
subnet 50.2.0.0 netmask 255.255.0.0 {

# modem config file
filename "amerilink-modem.cfg";

# time of day
option time-servers 50.1.1.100;
option ntp-servers 50.1.1.100;

# tftp server
next-server 50.1.1.100;

option routers 50.2.1.1;

host cm1 {
hardware ethernet AABBCC:000001;
fixed address 50.2.1.101;
}

host cm2 {
hardware ethernet AABBCC:000002;
fixed address 50.2.1.102;
}
}
```


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```
# MOONLINK's network
subnet 80.2.0.0 netmask 255.255.0.0 {

# modem config file
filename "moonlink-mdem.cfg";

# time of day
option time-servers 80.1.1.100;
option ntp-servers 80.1.1.100;

# tftp server
next-server 80.1.1.100;

option routers 80.2.1.1;

host cm1 {
hardware ethernet DDEEFF:000001;
fixed address 80.2.1.101;
}

host cm2 {
hardware ethernet DDEEFF:000002:
fixed address 80.2.1.102;
}
}
```


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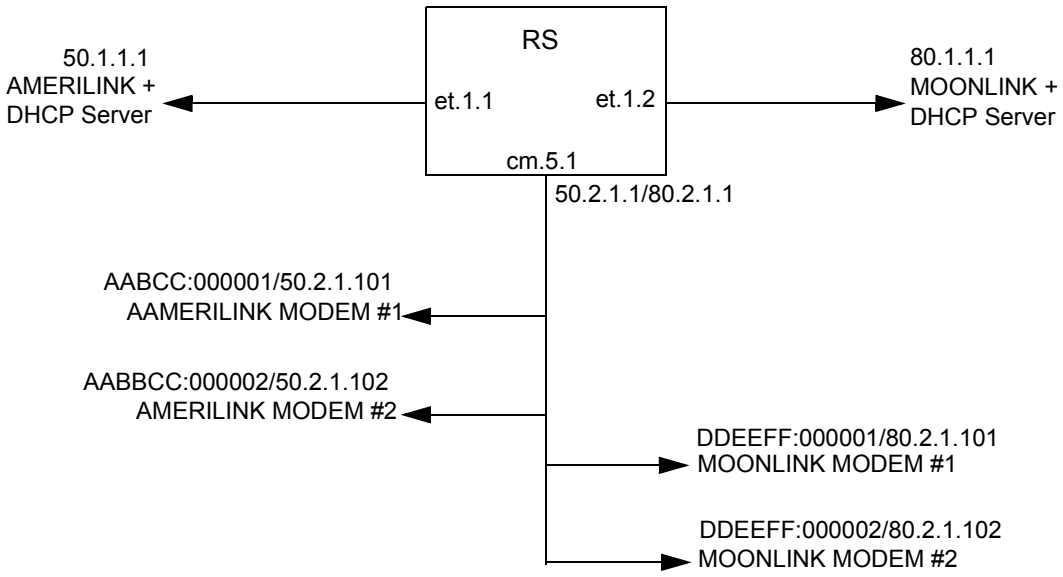
7.7.2 Example Two: Multiple ISPs with multiple DHCP servers

The advantages of this type of configuration are that each ISP manages its own DHCP server, and ISP selection is transparent to the user. The disadvantage is that the MAC to IP address mappings must be mutually exclusive. Otherwise, DHCP conflicts will result.



Following, is the configuration:

```
! Configure the RS
cmts set headend cm.5.1 auth-str DOCSIS
cmts set uschannel cm.5.1 upstream 1 state on

! Configure the VLANs
vlan create AMERILINK port-based
vlan create MOONLINK port-based
vlan create CMTS port-based
vlan add ports et.1.1 to AMERILINK
vlan add ports et.1.2 to MOONLINK
vlan add ports cm.5.1 to CMTS
interface create ip AMERILINK address-netmask 50.1.1.1/16 vlan
AMERILINK
interface create ip MOONLINK address-netmask 80.1.1.1/16 vlan MOONLINK

! The RF interface has overlapping subnets, one for AMERILINK and the other for
! MOONLINK
interface create ip CMTS address-netmask 50.2.1.1/16 vlan CMTS
interface add ip CMTS address-netmask 80.2.1.1/16
ip helper-address interface CMTS 50.1.1.100
ip helper address interface CMTS 80.1.1.100
```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Following, is the AMERILINK DHCP configuration:

```
# prevents unknown hosts from getting information from this dhcp server
deny unknown-clients;

# modem config file
filename “amerilink-modem.cfg”;

# time of day
option time-servers 50.1.1.100;
options ntp-servers 50.1.1.100;

# tftp server
next server 50.1.1.100;

shared network amerilink_moonlink {

# AMERILINK’s network : OK TO CONFIGURE
subnet 50.2.0.0 netmask 255.255.0.0 {
option routers 50.2.1.1;

host cm1 {
hardware ethernet AABBCC:000001;
fixed address 50.2.1.101;
}

host cm2 {
hardware ethernet AABBCC:000002;
fixed address 50.2.1.102;
}
}

# MOONLINK’s network: DON’T CONFIGURE!
subnet 80.2.0.0 netmask 255.255.0.0 {
}
}
```


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Following, is the MOONLINK DHCP configuration:

```
# prevents unknown hosts from getting information from this dhcp server
deny unknown-clients;

# modem config file
filename “moonlink-modem.cfg”;

# time of day
option time-servers 80.1.1.100;
options ntp-servers 80.1.1.100;

# tftp server
next server 80.1.1.100;

shared network amerilink_moonlink {

# AMERILINK’s network : DON’T CONFIGURE
subnet 50.2.0.0 netmask 255.255.0.0 {
}

# MOONLINK’s network : OK TO CONFIGURE
subnet 80.2.0.0 netmask 255.255.0.0 {

option routers 80.2.1.1;

host cm1 {
hardware ethernet DDEEFF:000001;
fixed address 80.2.1.101;
}

host cm2 {
hardware ethernet DDEEFF:000002;
fixed address 80.2.1.102;
}
}
}
```


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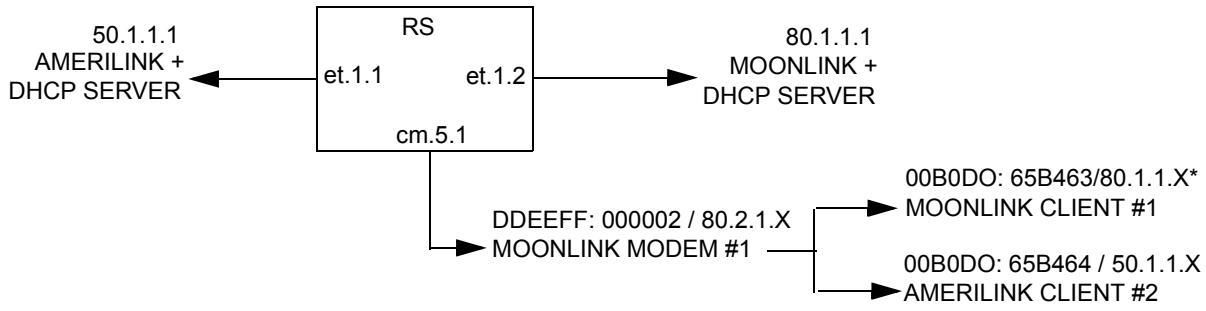
7.7.3 Example Three: Overlapping VLANs with Multiple DHCP Servers and Client-VLAN Bindings

The advantage of the client-VLAN bindings configuration is that clients and modems can be on different VLANs. This provides the added flexibility of using modems and Client Premise Equipment (CPEs) in different subnets. Client-VLAN bindings can be configured either from the CLI or through vendor extensions. See *TFTP Configuration Files* for information about vendor extensions.



Following, is the configuration:

```
! Configure the RS
cmts set headend cm.5.1 auth-str DOCSIS
cmts set uschannel cm.5.1 upstream 1 state on

! cm.5.1 must be a trunk port in order to support overlapping VLANs
vlan make trunk-port cm.5.1
vlan create AMERILINK port-based
vlan create MOONLINK port-based
vlan add ports et.1.1 to AMERILINK
vlan add ports cm.5.1 to AMERILINK
vlan add ports et.1.2 to MOONLINK
vlan add ports cm.5.1 to MOONLINK
interface create ip AMERILINK address-netmask 50.1.1.1/16 vlan
AMERILINK
interface create ip MOONLINK address-netmask 80.1.1.1/16 vlan MOONLINK!

! Bind the client to the VLAN
cmts set modem cm.5.1 macaddr DDEEFF:000002 vlan MOONLINK
cmts set cpe   cm.5.1 macaddr 00B0DO:65B463 vlan MOONLINK
cmts set cpe   cm.5.1 macaddr 00B0DO:65B464 vlan AMERILINK
```

TFTP Configuration Files

Client-VLAN bindings can be specified in the modem's TFTP configuration file rather than from the CLI. This file is configured manually through a configuration editor or by provisioning server software. Although TFTP configuration files are part of the DOCSIS standard, some modems may not be capable of recognizing vendor extensions. A vendor extension is the line in the file that identifies a vendor. See the first line in the file below.

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Here is an example of a TFTP configuration file

```
! This line indicates that this vendor extension is a Riverstone CMTS
43(VSIF) + n1(number of value bytes inside this VSIF) 8(Vendor ID Type)
+ 3(len) + 02:E0:63(Riverstone OUI)
! TLVs
1 (Default Vlan) + n2(number of value bytes)
      1 (Default Vlan ID) + 2(len) + [1-4094]
      2 (Default Vlan Priority) + 1(len) + [0-7] /* Optional */
      3 (Default Vlan Type) + 1(len) + [protocol bitmask] /* Optional */
2 (MAC-IP-VLAN binding) + n3(number of value bytes)
      1 (MAC Address) + 6(len) + XXXXXX:XXXXXX
      2 (Default Vlan ID) + 2(len) + [1-4094]
      3 (Default Vlan Priority) + 1(len) + [0-7] /* Optional */
      4 (Default Vlan Type) + 1(len) + [protocol bitmask] /* Optional */
      5 (IP Address) + 4(len) + X.X.X.X
```

Protocol bitmasks are defined as:

- **IP** – 0x01
- **IPX** – 0x02
- **OTHER** – 0x80

Note To specify both IP and IPX, OR the values together to yield 0x03

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7.8 ANTI-SPOOFING

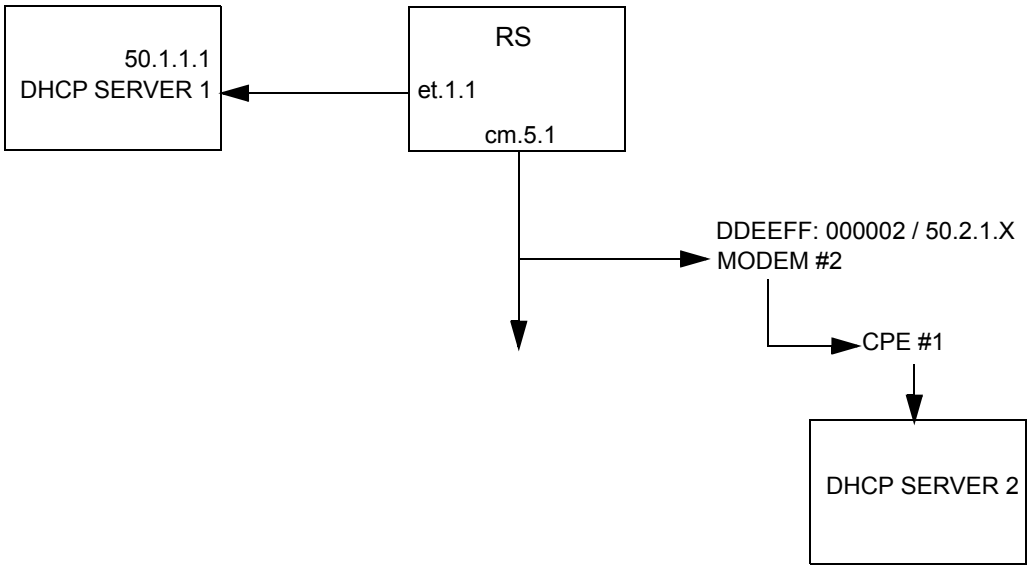
The following examples illustrate methods for anti-spoofing using the RS.

The RS in these examples contain the following line cards:

- Slot 1: 8 port 10/100 card
- Slot 5: CMTS card

7.8.1 Anti-DHCP Spoofing

Anti-DHCP spoofing prevents a DHCP server that is behind a cable modem from serving as a *provisioning* server for nodes on the same cable network. In this example, DHCP anti-spoofing prevents DHCP SERVER #2 from serving as a provisioning server instead of DHCP SERVER #1.



Following, is the configuration:

```
! Configure the RS
cmts set headend cm.5.1 hashed-auth-str hbCgHB
cmts set uschannel cm.5.1 upstream 1 state on
! Configure the VLANs
vlan create dhcp port-based
vlan create cmts port-based
vlan add ports et.1.1 to dhcp
vlan add ports cm.5.1 to cmts
interface create ip dhcp address-netmask 50.1.1.1/16 vlan dhcp
interface create ip cmts1 address-netmask 50.2.1.1/16 vlan cmts
! Enable anti-DHCP spoofing
cmts set headend cm.5.1 anti-dhcp-spoofing enable
```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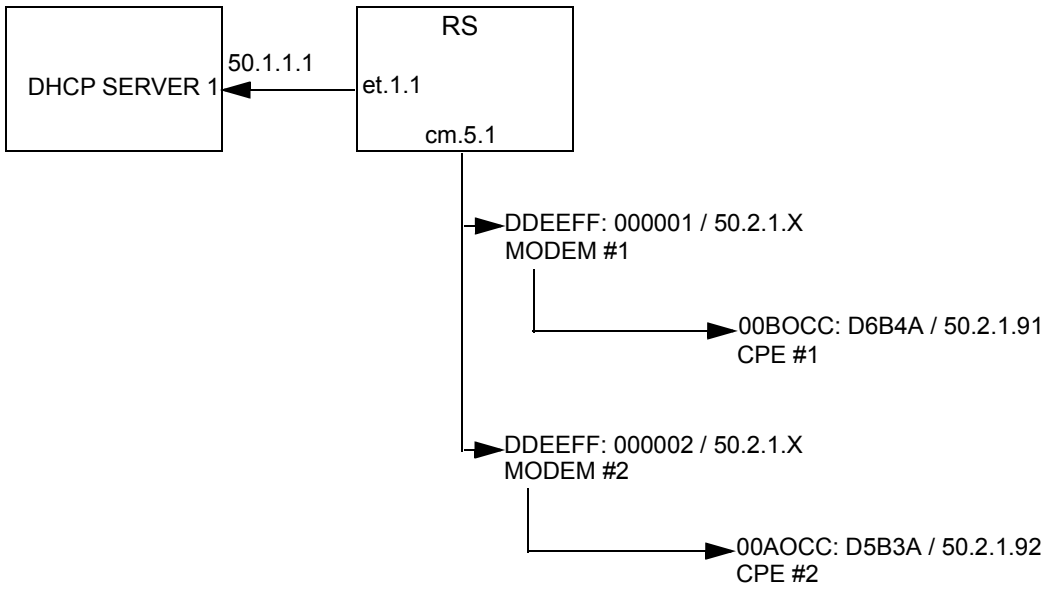
7.8.2 Anti-IP-spoofing

Anti IP-spoofing prevents CPE's on the same network segment from cloning other CPE addresses. In this example, anti-spoofing prevents CPE #1 from cloning CPE #2's IP address.



Here is the configuration for the RS:

```
! Configure the RS
cmts set headend cm.5.1 hashed-auth-str hbCgHB
cmts set uschannel cm.5.1 upstream 1 state on
! Configure the VLANs
vlan create dhcp port-based
vlan create cmts port-based
vlan add ports et.1.1 to dhcp
vlan add ports cm.5.1 to cmts
! Create the interfaces
interface create ip dhcp address-netmask 50.1.1.1/16 vlan dhcp
interface create ip cmts1 address-netmask 50.2.1.1/16 vlan cmts
```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Static and Dynamic Anti-IP Spoofing

IP-spoofing can be implemented statically or dynamically. The following sections give examples of each type of anti-spoofing.

Static Anti-IP Spoofing

Static configuration requires manually assigning an individual MAC address to an individual IP address.

Here is an example:

```
! Configure static anti-IP spoofing
cmts set headend cm.5.1 anti-ip-spoofing enable
cmts set cpe cm.5.1 macaddr 00BOCC:D6B4A ip 50.2.1.91
cmts set cpe cm.5.1 macaddr 00AOCC:D5B3A ip 50.2.1.92
```

Dynamic Configuration of Anti-IP Spoofing

In dynamic configuration, a *snoop function* snoops DHCP packets to find IP address/MAC address information. If anti-IP spoofing is enabled, the information is used to prevent spoofing. To prevent spoofing, the IP address/MAC address pairs are stored in a data base and are used to check for spoofed IP addresses.

Note Dynamic configuration is enabled using the **anti-ip-spoofing** command in conjunction with the **dhcp-ipaddr-snoop** command.

Here is an example.

```
! Configure dynamic anti-IP spoofing
cmts set headend cm.5.1 anti-ip-spoofing enable
cmts set headend cm.5.1 dhcp-ipaddr-snoop enable
```

Implementing DHCP-strict forces all CPEs to use DHCP. This implementation provides strict provisioning over IP address usage. Here is the command to implement
DHCP-strict:

```
! Enable dhcp strict
cmts set headend cm.5.1 dhcp-strict
```


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8 ATM CONFIGURATION GUIDE

This chapter provides an overview of the Asynchronous Transfer Mode (ATM) features available for the Riverstone RS Switch Router. ATM is a cell switching technology used to establish multiple connections over a physical link. In addition, you can configure each of these connections with its own traffic parameters, providing more control over specific connections within a network.

The ATM line card provides an ATM interface, allowing integration of ATM with Ethernet and other interfaces within a network topology supported by the Riverstone RS Switch Router. This chapter discusses the following tasks:

- Configuring ATM ports
- Configuring virtual channels
- Traffic shaping
- Managing traffic
- Bridging ATM traffic
- Routing ATM traffic
- Configuring point-to-point connections (PPP)

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8.1 CONFIGURING ATM PORTS

You can use two different ATM line cards on the RS, the ATM multi-rate line card and the ATM-OC12 line card. The multi-rate line card has two available slots for various Physical Layer (PHY) interface cards. These PHY cards provide the media-specific portion of an ATM interface. The ATM-OC12 line card provides one logical connection through two physical ports (Link1 and Link 2). For additional information on these modules, refer to the *Riverstone RS Switch Router Getting Started Guide*.

This section describes the various commands you can use to control the functionality of the ports on the ATM line cards. Use the "at" prefix when specifying an ATM port in the CLI commands. For example, the first port on slot 5 would be "at.5.1."

8.1.1 Configuring SONET Parameters

ATM utilizes synchronous optical network (SONET) encapsulation to transmit cells through a link. You can configure the following SONET features on the ATM line cards:

- Set the Circuit-ID
- Set SONET/SDH Framing
- Set Loopback Mode
- Enable Path Tracing
- Enable Payload Scrambling
- Enable Stream Scrambling

Note For a complete description of the SONET features, refer to Section 9, *"Packet-over-SONET Configuration Guide."* Refer to the SONET chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a description of the SONET commands.

Configuring Automatic Protection Switching (APS) on the ATM OC-12 Line Card

You can configure APS on the ATM OC-12 line card. This allows for redundancy for the ATM port in case there is an interruption or failure on a link. APS specifies a working port (primary) and a protecting port (backup).

The ATM OC-12 line card has two physical ports: **Link1** and **Link2**. However, there is only one logical port. The **Link1** port is the working port (primary port), and **Link2** is the protecting port (backup port). Note that you cannot configure a connection on the **Link2** port that is different from the **Link 1** port. The **Link2** port operates identically to the **Link1** port, acting solely as the backup port in the case of link interruption or failure.

Note Refer to the SONET Chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a complete description of the APS commands available on the Riverstone RS Switch Router.

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8.1.2 Setting Parameters for the Multi-Rate Line Card

On the multi-rate line card you can do the following:

- Enable cell scrambling for the PDH (plesiochronous digital hierarchy) physical (PHY) interfaces available on the ATM line card, such as the T3 and E3 PHYs.
- Select the format for mapping ATM cells into PDH (plesiochronous digital hierarchy) T3 and E3 frames.
- Change the default number of bits allocated for the Virtual Path Identifier (VPI).

Cell Scrambling

Cell scrambling is useful for optimizing the transmission density of the data stream. Since all transmissions use the same source clock for timing, scrambling the cell using a random number generator converts the data stream to a more random sequence. This ensures optimal transmission density of the data stream.

Note Refer to the SONET Chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for information about cell scrambling on SONET PHY interfaces.

In the following example, cell scrambling is enabled on port at.5.1:

```
rs(config)# atm set port at.5.1 pdh-cell-scramble on
```

Cell Mapping

The ATM cells are mapped into a PDH (E3, T3) frame using two different mapping formats. The default mapping format for the ATM multi-rate line card is *direct* ATM cell mapping (default). For compatibility purposes, you can change the mapping format to physical layer convergence protocol (PLCP) as shown in the following example:

```
rs(config)# atm set port at.5.1 cell-mapping plcp
```

VPI Bit Allocation

The VPI defines a virtual path. A virtual path is a bundling of virtual channels transversing across the same physical connection. The actual number of virtual paths and virtual channels available on an ATM port depends upon how many bits are allocated for the VPI and VCI, respectively.

The number of bits allocated define the number of VPI and VCI values available for that port. The following equations define the number of virtual paths and virtual channels:

# of virtual paths = 2^n; where n is the number of bits allocated for VPI

# of virtual channels = $2^{(12-n)}$; where $(12-n)$ is the number of bits allocated for VCI, and n is the number of bits allocated for VPI

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The ATM OC-12 line card has a preset bit allocation scheme for the VPI/VCI pair which *cannot* be changed: 4 bits set for VPI and 12 bits set for VCI. The ATM multi-rate line card has a default bit allocation of 1 bit allocated for the VPI and 11 bits allocated for the VCI. This default bit allocation scheme provides a VPI range=(0,1) and # of virtual channels=2^n=2^{11}=2048. If you require more VPIs, you will need to set your VPI bits to some number higher than 1. But because there are only 12 bits available for VPI/VCI pairs on an ATM port, the more bits you allocate for VPI, the fewer bits remain for VCI.

The bit allocation command allows you to set the number of bits allocated for the VPI on the ATM multi-rate line card; the remaining number of bits are allocated for VCI. In the following example, the VPI bit allocation for port at.5.1 is set to 2:

```
rs(config)# atm set port at.5.1 vpi-bits 2
```

8.1.3 Displaying Port Information

You can display the parameters set for an ATM port. The following is an example of the information that is displayed with the **`atm show port-settings`** command for a PDH PHY interface:

```
rs(atm-show)# port-settings at.9.1
Port information for Slot 9, Port 1:
    Port Type:          T3 ATM coaxial cable
    Xmt Clock Source:   Local
    Scramble Mode:      Payload
    Line Coding:        B3ZS
    Cell Mapping:       Direct
    Framing             Cbit-Parity
    VC Mode:            1 bit of VPI, 11 bits of VCI
    Service Definition: user-default-OC3
        Service Class:      UBR
        Peak Bit Rate:      Best Effort
        Sustained Bit Rate: 0 Kbits/sec (0 cps)
        Maximum Burst Size: 0 cells
        Encapsulation Type: VC-MUX
        F5-OAM:             Requests & Responses
```

The following is an example of the information that is displayed with the **`atm show port-settings`** command for a SONET PHY interface:

```
rs(atm-show)# atm show port-settings at.7.1
Port information for at.7.1:
    Port Type:            SONET STS-3c MMF
    Media Type:           SONET
    Xmt Clock Source:     Local
    VC Mode:              1 bit of VPI, 11 bits of VCI
    Reservable Bandwidth: 309057 CPS, 131040168 bits/sec
    OAM Timers:           Detect Up: 15, Down: 15
    Service Definition:   default-OC3
        Service Class:      UBR
        Peak Bit Rate:      Best Effort
        Encapsulation Type: LLC Multiplexing
        Traffic Type:       RFC-1483, multi-protocol
        F5-OAM:             Responses Only
```


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8.2 CONFIGURING VIRTUAL CHANNELS

A virtual channel is a point-to-point connection that exists within a physical connection. You can create multiple virtual channels within one physical connection, with each virtual channel having its own traffic profile.

The combination of VPI and VCI is known as the VPI/VCI pair, and identifies the virtual channel. Hence, if a VC is configured with a certain VPI/VCI pair on one end of the physical link, the port at the other end must have the same VPI/VCI pair to complete the connection.

Note Never use VCI numbers 0 through 31. These VCIs are used for signaling purposes.

In the following example, a virtual channel on slot 5, port 1 is created with a VPI of 1 and a VCI of 100

```
rs(config)# atm create vcl port at.5.1.1.100
```

After you configure a virtual channel you can apply traffic shaping and QoS parameters to manage the traffic on the VC. For traffic shaping parameters, refer to *"Traffic Shaping."* For information on QoS, refer to *"Traffic Management."*

8.2.1 Gathering Traffic Statistics (OC-12)

Enabling traffic statistics allows you to gather and display various statistics about the virtual channel, including "RMON-like" statistics, counts of frames sent and received, unicast/broadcast/multicast frames sent and received, etc

In the following example, traffic statistics are enabled on port 5.1.1.100

```
rs(config)# atm set vcl port at.5.1.1.100 traffic-stats-enable
```


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To display traffic statistics for a virtual channel, use the **atm show stats** command as shown in the following example:

```
RS-8000# atm show stats port at.5.1.1.100
PORT = 1, VPI = 1, VCI = 100
                                      Received    Transmitted
                                      --------    -----------
SAR statistics:
    Packets discarded                        0              0
    Packets Reassembled/Segmented          119            119
    Received cells                         119            119
AMAC statistics:
    Unicast                                  0              0
    Multicast                                0              0
    Broadcast                                0              0
    Discarded                                0              0 (includes sent to ACPU)
    <64 bytes                                0              0
    63<  <256                                0              0
    255< <1519                               0              0
    >1518                                    0              0
                                       Enabled        Up/Down
                                       -------        -------
OAM status                                  No            N/A
Statistics Cleared      * Never Cleared *
```

Note that the last line of the example shows that the statistics were never cleared. You can clear traffic statistics on a port by using the **atm clear stats** command.

8.3 TRAFFIC SHAPING

You can set traffic parameters for a virtual channel by specifying a service category. A service category defines bandwidth characteristics and delay guarantees. You can then apply a different service category to each virtual channel. This gives you more control of your network resources, and more options to accommodate different user needs.

You can define the following service categories:

Unspecified Bit Rate (UBR) — This service category is strictly best effort and runs at the available bandwidth. Users may limit the bandwidth by specifying a PCR value. The SCR and MBS are ignored. This service class is intended for applications that do not require specific traffic guarantees. UBR is the **default**.

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Constant Bit Rate (CBR)	This service category provides a guaranteed constant bandwidth specified by the Peak Cell Rate (PCR). This service requires only the PCR value. The Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS) values are ignored. This service category is intended for applications that require constant cell rate guarantees such as uncompressed voice or video transmission.
Non Real-Time Variable Bit Rate	This service category provides a guaranteed constant bandwidth (specified by the SCR), but also provides for peak bandwidth requirements (specified by the PCR). This service category requires the PCR, SCR, and MBS options and is intended for applications that can accommodate bursty traffic with no need for real-time guarantees.
Real-Time Variable Bit Rate	This service category provides a guaranteed constant bandwidth (specified by the SCR), but also provides for peak bandwidth requirements (specified by the PCR). This service category requires the PCR, SCR, and MBS options and is intended for applications that can accommodate bursty real-time traffic such as compressed voice or video.
Available Bit Rate (ABR)	This service category guarantees a minimum cell rate only, intended for best effort applications. This service category is currently unsupported.

After you define a service category, you apply it to a VC. An important concept when applying service profiles is the concept of *inheritance*. Since a service profile can be applied to a virtual channel, virtual path, or an ATM port, the actual connection can inherit the service profile from any one of the three. The virtual channel will inherit the service profile that is directly applied on it. If no service profile was applied to the virtual channel, the connection will inherit the service profile applied to the virtual path. If no service profile was applied to the virtual path, then the connection will inherit the service profile applied to the ATM port. If no service profile was applied to the port, then the default service class UBR is applied.

The following example defines a service profile named ‘cbr1m’ where CBR is the service category and peak cell rate is set to 10000 kcells/second. The service profile is then applied to the VC (VPI=0, VCI=100) on ATM port at.1.1:

```
rs(config)# atm define service cbr1m srv-cat cbr pcr 10000
rs1(config)# atm apply service cbr1m port at.1.1.0.100
```

To display information about the service you configured, use the **`atm show service`** command as shown in the following example:

```
rs# atm show service cbr1m
cbr1m
    Service Class:      CBR
    Peak Bit Rate:      10000 Kbits/sec (23584 CPS)
    Encapsulation Type: LLC Multiplexing
    Traffic Type:       RFC-1483, multi-protocol
    F5-OAM:             Responses Only
```


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8.4 TRAFFIC MANAGEMENT

The ATM line cards provide different methods for managing traffic. On the ATM multi-rate line card you can use the following QoS policies to control ATM traffic: Strict Priority, Weighted Fair Queueing (WFQ), or WFQ with Strict Priority.

On the ATM OC-12 line card you can prioritize traffic by configuring virtual channel (VC) groups. Each VC within a VC group can be assigned one (or more) of four internal levels: low, medium, high, and control. These levels prioritize the separate VCs, and as a result prioritize the traffic passing through the separate VCs within the VC group.

8.4.1 Configuring QoS (Multi-Rate Line Card)

You can use the **`atm set vcl-qos`** command to set the following QoS policies on the ATM multi-rate line card:

- Strict Priority (Default)

  Separate buffer space is allocated to each of the following four queues: control, high, medium and low. Buffered traffic is forwarded in the following order: traffic in the control queue is forwarded first, followed by traffic in the high queue, medium queue, and finally, the low queue. When using strict priority, no control packets are dropped if the rate of the control packets is less then the VC's rate. But if the rate of control packets exceeds the VC's rate, then some control packets must be dropped.

  This policy ensures that critical traffic reaches its destination even if the exit ports for the traffic are experiencing greater-than-maximum utilization. To prevent traffic from queues that are forwarded first from starving traffic from other queues, you can apply the WFQ queuing policy to set a minimum bandwidth for each queue.

- Weighted Fair Queuing

  When you use WFQ, you divide the VC's bandwidth and assign percentages to each queue (control, high, medium and low). These percentages must be at least 10%, and must total 100%. This queueing policy is set on a per-port basis.

- Weighted Fair Queuing with Strict Priority

  With this combination of Strict Priority and WFQ, the control queue gets potentially all of the link bandwidth. The remaining bandwidth is shared among the other priorities, according to the user-specified percentages. With this policy, you specify percentages for the high, medium, and low queues only.

Note Currently, QoS only supports packets of Ethernet size 1514 and smaller. For packets larger than this, the accuracy of QoS cannot be guaranteed.

QoS is triggered only when there is congestion on the link (i.e., the transmit queue for any VC reaches a pre-determined depth). Until congestion occurs, the traffic is transmitted on a first-come-first-serve basis, and may not match the requested percentages.

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Relative Latency

When you use the **atm set vcl-qos** command to define a VC's QoS policy, you can set a value for relative latency by specifying the **relative-latency** parameter. Increasing relative latency can increase the accuracy of the achieved rates. This is because each queue has a quota of bytes to transmit, and the packets that are sent may not exactly equal that quota. Therefore there is going to be either excess bytes sent, or a shortage of bytes sent. When a packet to transmit exceeds the quota, an implementation could choose to send the packet and go over the quota, or not send it and go under the quota. This feature allows an excess number to be sent, so up to 1499 extra bytes can be sent during a period. This is a significant number when the byte count for a queue is around 1500; however, its affect decreases as the byte count increases.

Increasing the relative latency also increases the amount of time that a queue waits to transmit a packet after it has used up its quota. For example, if a queue with weight 10 used up its quota before the other queues had transmitted, it would potentially have to wait for the other 90 percent of the total byte count to be sent before it could send again. The time is dependent upon the VC's rate.

For configurations in which a latency sensitive application has a low percentage of a slow link speed, it is best to put that application on the control queue and use "WFQ with strict priority." Optionally, you can set the relative latency to 1, as long as the achieved rates are accurate.

Additionally, when increasing relative latency values, you should also consider increasing the size of the buffers. This is because packets may be held off for longer times.

Decreasing relative latency has the effect of:

- Decreasing worst case latency seen by a bursty flow.
- Decreasing buffer requirements for the VC.
- Possibly decreasing the achievable accuracy of the selected weights.

Controlling Buffers for Each VC

When VCs queue data, they consume memory resources on the ATM card. By default, the hardware limits the number of internal buffers that each VC can use (21 * 240 bytes) for each queue. Generally, you should not have to set the number of internal buffers. However, if a bursty application is suffering loss (i.e., jumpy video), then you can increase the buffers for that queue by using the **atm set vcl-buffering** command. The best way to determine the correct setting is to use a network analyzer to find the maximum burst, or to determine the correct settings through experimentation.

8.4.2 Configuring Virtual Channel Groups (OC-12)

A virtual channel group is a grouping of up to four separate virtual channels. This grouping of virtual channels is treated as one large virtual circuit. This is due to the fact that the VC group is seen as one virtual interface by the IP layer. For example, OSPF will see a point-to-point connection instead of multiple connections for all the virtual channels within the VC group.

Each VC within a virtual channel group can be assigned one (or more) of four internal priority levels: low, medium, high, and control. These internal priority levels apply to IP packets.

In addition to assigning an internal priority level for a VC, you can also designate a VC within the VC group to carry broadcast/multicast traffic.

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This feature is advantageous in the case where different priority traffic needs to travel between two end devices. The end devices can essentially share one logical connection (through the VC group) while still prioritizing data up to four different levels. If a connection becomes oversubscribed and packets start dropping, using a VC group ensures that the data traffic passing between the two end devices are ranked by importance.

Creating a Virtual Channel Group

To configure a VC group, you should:

1. Create the VCs using the **`atm create vcl`** command.
2. Create the VC group using the **`atm create vcgroup`** command.
3. Add up to four separate virtual channels to the group using the atm add vcl command. You can also set a priority level for each VC within the VC group, as well as designate one of the VCs to handle broadcast-multicast traffic.

   If you add less than four virtual channels to a VC group, the next lower priority virtual channel will handle the traffic that lacks a particular VC for its priority. For example, you add two VCs (one low priority and one high priority) to a VC group. If a medium priority packet comes in, then the next lower priority VC, the VC low, will handle the packet.

Note You cannot add a virtual channel with forced-bridged enabled to a VC group.

Applying Service Profiles to VC Groups

Either the virtual channel or the VC group may have a service profile applied, but not both. You must first negate the separate service profiles from each virtual channel before trying to apply a service profile to the whole VC group, and vice versa.

It is recommended that you pay special attention when selecting the ATM service parameters for the VCs with different IP priorities. For example, control priority needs to have some dedicated bandwidth allocated while the low priority VC could have UBR defined with no dedicated bandwidth.

8.4.3 Traffic Management Configuration Example

The examples in this section show how you can manage traffic using QoS policies on the ATM multi-rate line card, and using VC groups on the ATM OC-12 line card.

Suppose you are a network administrator in charge of managing a network with three Client workstations (Client1, Client2, Client3) and a server. You are using two RS's to connect and manage traffic between the server and the clients.

Your network requirements are as follows:

- Traffic from the Server heading to Client1 is assigned high priority in the event that the connection becomes oversubscribed.
- Traffic from the Server heading to Client2 is assigned medium priority in the event that the connection becomes oversubscribed.
- Traffic from the Server heading to Client3 is assigned low priority in the event that the connection becomes oversubscribed.

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- All routing protocol control packets are assigned control priority.

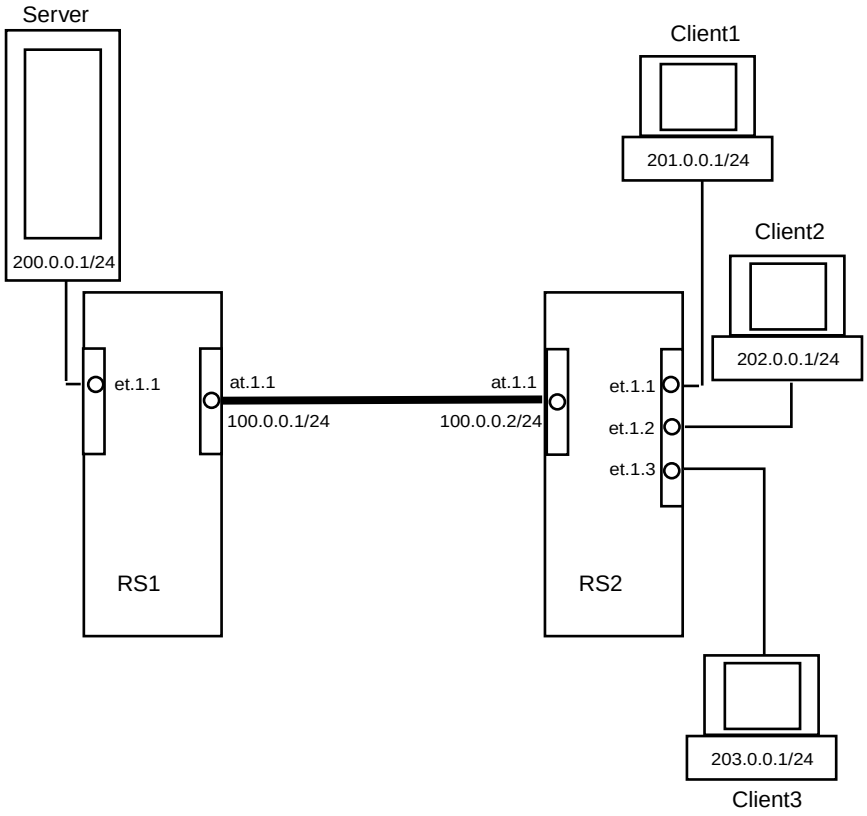

Figure 8-1 Traffic management sample configuration

The following sections illustrate how to accommodate the network requirements if the RS's are connected through ATM multi-rate line cards, and if the RS's are connected through ATM OC-12 line cards.

Configuring QoS Policies (Multi-Rate Line Card)

If the routers in Figure 8-1 were connected through ATM multi-rate line cards, then you would use QoS policies to manage the traffic.

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Following are the steps and commands used to configure RS1 in the example:

Create a virtual channel.
```
atm create vcl port at.1.1.0.100
```

Configure an interface on the ATM port.
```
interface create ip atm1 address-netmask 100.0.0.1/24 port at.1.1.0.100
```

Configure an interface on the ethernet port to which the server is connected.
```
interface create ip 200.0.0.1/24 port et.1.1
```

Configure a static IP route to the 3 different clients, specifying the VC interface as the gateway.
```
ip add route 201.0.0.1/24 gateway 100.0.0.2/24
ip add route 202.0.0.1/24 gateway 100.0.0.2/24
ip add route 203.0.0.1/24 gateway 100.0.0.2/24
```

Set the priority levels for the different flows on RS1. This step is necessary in differentiating the priority levels of traffic data intended for the different clients.
```
qos set ip to_client1 high 200.0.0.1/24 201.0.0.1/24
qos set ip to_client2 medium 200.0.0.1/24 202.0.0.1/24
qos set ip to_client3 low 200.0.0.1/24 203.0.0.1/24
```

Define the QoS policy, which in this example is WFQ with Strict Priority. Therefore a percentage is not specified for the control queue.
```
atm set vcl-qos port at.1.1.0.100 low 20 medium 30 high 50
```

Following are the steps and commands for configuring RS2 in the example:

Create the virtual channel on RS2
```
atm create vcl port at.1.1.0.100
```

Configure an interface on the ATM port.
```
interface create ip atm1 address-netmask 100.0.0.2/24 port at.1.1.0.100
```

Configure an interface on the ethernet port to which each client is connected.
```
interface create ip 201.0.0.1/24 port et.1.1
interface create ip 202.0.0.1/24 port et.1.2
interface create ip 203.0.0.1/24 port et.1.3
```


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Configuring Virtual Channels Groups (OC-12)

If the RS's in Figure 8-1 were connected through ATM OC-12 line cards, you would use VC groups to manage the traffic. Following are the steps and commands for configuring RS1 in the example:

Create the virtual channels.

```
atm create vcl port at.1.1.0.100
atm create vcl port at.1.1.0.101
atm create vcl port at.1.1.0.102
atm create vcl port at.1.1.0.103
```

Create a virtual channel group 'vg.1' on slot number 1 of RS1.

```
atm create vcgroup vg.1 slot 1
```

Add the 4 virtual channels into the VC group. This step also identifies the priority level for each of the 4 virtual channels within the group.

```
atm add vcl at.1.1.0.100 to vg.1 priority low
atm add vcl at.1.1.0.101 to vg.1 priority medium
atm add vcl at.1.1.0.102 to vg.1 priority high
atm add vcl at.1.1.0.103 to vg.1 priority control
```

Configure an IP address for the VC group.

```
interface create ip vcg1 address-netmask 100.0.0.1/24 port vg.1
```

Configure a static IP route to the 3 different clients, specifying the VC group interface as the gateway.

```
ip add route 201.0.0.1/24 gateway 100.0.0.2/24
ip add route 202.0.0.1/24 gateway 100.0.0.2/24
ip add route 203.0.0.1/24 gateway 100.0.0.2/24
```

Set the priority levels for the different flows on RS1. This step is necessary in differentiating the priority levels of traffic data intended for the different clients. Note that control packets are assigned to control priority levels by default.

```
qos set ip to_client1 high 200.0.0.1/24 201.0.0.1/24
qos set ip to_client2 medium 200.0.0.1/24 202.0.0.1/24
qos set ip to_client3 low 200.0.0.1/24 203.0.0.1/24
```


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Following are the steps and commands for configuring RS2:

```
Create the same virtual channels on RS2.
rs2(config)# atm create vcl port at.1.1.0.100
atm create vcl port at.1.1.0.101
atm create vcl port at.1.1.0.102
atm create vcl port at.1.1.0.103

Create the virtual channel group 'vg.1' on slot number 1 of RS2.
atm create vcgroup vg.1 slot 1

Add the virtual channels to the VC group created on RS2.
atm add vcl at.1.1.0.100 to vg.1 priority low
atm add vcl at.1.1.0.101 to vg.1 priority medium
atm add vcl at.1.1.0.102 to vg.1 priority high
atm add vcl at.1.1.0.103 to vg.1 priority control

Configure an IP address for the VC group.
interface create ip vcg1 address-netmask 100.0.0.2/24 port vg.1
```

Use the **`atm show vcgroup`** command to display information about a virtual channel group:

```
rs# atm show vcgroup port vg.1
Port           Control      High         Medium       Low          Bcast
               Vpi  Vci     Vpi  Vci     Vpi  Vci     Vpi  Vci
vg.1     Conf  1    103     1    102     1    101     1    100     LOW
vg.1     Actv  0    0       0    0       0    0       0    0
rs#
```


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8.5 BRIDGING ATM TRAFFIC

The ATM modules support both flow-based and address-based bridging. Like all the other RS modules, the ATM modules perform address-based bridging by default, but can be configured to perform flow-based bridging. The ATM multi-rate line card supports IP-based VLANs, and the ATM OC-12 line card supports IP and IPX-based VLANs. You can configure an ATM port as an 802.1Q trunk port, enabling it to carry traffic for multiple VLANs. For additional information on the RS bridging functions, refer to Section 5, *"Bridging Configuration Guide."*

Note The ATM modules do not support the Spanning Tree Protocol.

The following example illustrates how you can use bridging and VLANs to accommodate different networking requirements on an ATM module. In the network diagram, there are two client groups, VLAN A and VLAN B. These two client groups have very different needs and requirements for their users. VLAN A consists of users who need access to a high bandwidth connection able to support video conferencing. VLAN B consists of users who require less bandwidth and are mainly concerned with email and server backup traffic.

There are two separate VLANs in this network, VLAN A and VLAN B. VLAN A is connected to ethernet port et.5.1, and VLAN B is connected to ethernet port et.6.2.

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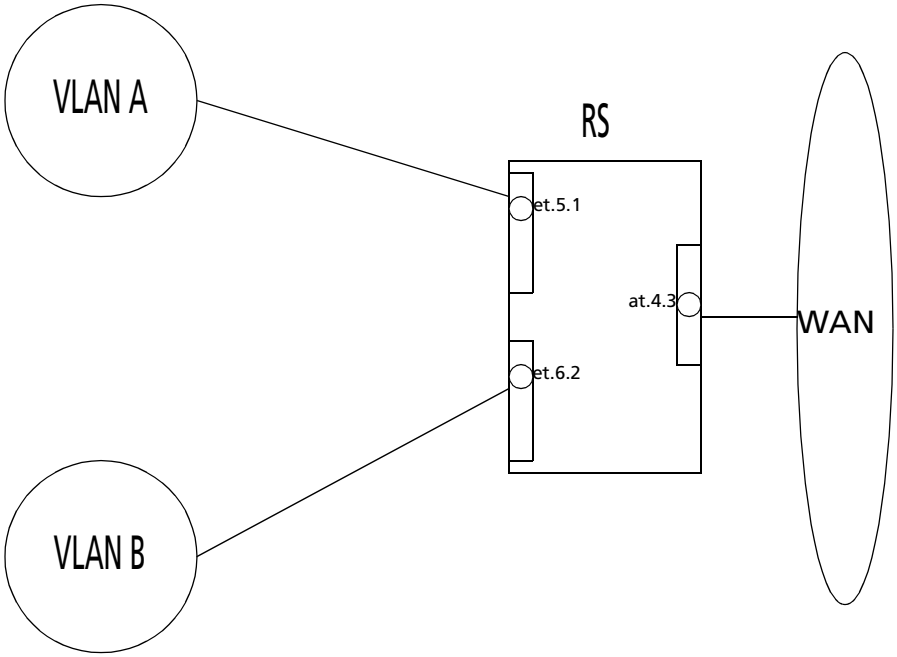

Figure 8-2 Bridging ATM traffic configuration example

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Following are the configuration steps for the example:

```
Apply an interface on both ethernet ports.
rs(config)# interface create ip subnetA address-netmask 11.1.1.1/24
port et.5.1 up
rs(config)# interface create ip subnetB address-netmask 11.1.2.1/24
port et.6.2 up

Create two virtual channels, one for each type of traffic.
rs(config)# atm create vcl port at.4.3.0.100
rs(config)# atm create vcl port at.4.3.0.101

Create the VLANs: VLAN A with ID number 1, and VLAN B with ID number 2.
rs(config)# vlan create VLAN_A ip id 1
rs(config)# vlan create VLAN_B ip id 2

Add the virtual channels to each VLAN.
rs(config)# vlan add ports et.5.1,at.4.3.0.100 to VLAN_A
rs(config)# vlan add ports et.6.2,at.4.3.0.101 to VLAN_B

Define a service class for VLAN A where CBR is the service category and peak cell rate is set to
100000 kcells/second to ensure proper support for video conferencing.
rs(config)# atm define service vlanA srv-cat cbr pcr 100000

Define a service class for VLAN B where UBR is the service category.
rs(config)# atm define service vlanB srv-cat ubr

Apply the appropriate service category to each VC.
rs(config)# atm apply service vlanA port at.4.3.0.100
rs(config)# atm apply service vlanB port at.4.3.0.101
```

8.5.1 Enabling Forced Bridging on a Virtual Channel

When Layer 3 traffic must travel through an intermediate Layer 2 cloud, such as an L2 switch, you can enable forced bridging on ATM ports. .Enabling forced-bridging forces the VC to encapsulate all ingress/egress traffic into a Layer 2 frame. As a result, all traffic passing through the VC has a MAC address inserted into the packet header.

In the following example, forced bridging is enabled on at.5.1.1.100:

```
rs(config)# atm set vcl port at.5.1.1.100 forced-bridged
```

.You can also enable forced bridging on a VC group. When you do so, it applies to all VCs in the group. You cannot enable forced-bridging on an individual basis.

8.5.2 Configuring Cross-Connects

You can configure a cross-connect on the RS to switch packets from a VC on one port to a second VC on another port. This is similar to ATM switching functionality, but packets instead of cells are switched. To configure the cross-connects, you need to specify the cross-connected ports. Then all traffic that is received on one VC is tunneled to the other VC.

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To switch packets between two ATM ports, you would specify the **atm set cross-connect** command for both ports. For example, to configure a cross-connect between at.1.1.0.100 and at.2.1.0.101, enter the following:

```
atm set cross-connect at.1.1.0.100 to at.2.1.0.101
atm set cross-connect at.2.1.0.101 to at.1.1.0.100
```

Note You can configure cross-connects on the multi-rate line card only.

8.5.3 Limiting MAC Addresses Learned on a VC

You can limit the number of MAC addresses learned on a VC. This security feature prevents users from purposely filling the L2 tables. You can set the limit between 0 and 127. However, at least one MAC address should be allowed on each VC.

When you specify a limit for the number of MAC addresses learned, that limit applies only to the additional MAC addresses that will be learned after the command was entered. If you specify a limit of 10 MAC addresses and the RS has already learned 3, then the total number of MAC addresses that can be learned on the VC is 13. But once enough MAC addresses have aged out to bring the number of addresses learned to below the limit you set, then the maximum number of MAC addresses learned will not exceed the limit.

The following example limits the number of MAC addresses learned on at.1.1.0.100:

```
atm set vcl port at.1.1.0.100 mac-addr-limit 10
```

8.6 ROUTING ATM TRAFFIC

Configuring IP and IPX interfaces for ATM modules is generally the same as for WANs and LANs. You assign an IP address to each interface and configure routing protocols such as OSPF or BGP. You can configure the IP interface on a physical port or as part of a VLAN. The ATM multi-rate line card supports IP-based VLANs, and the ATM OC-12 line card supports IP and IPX-based VLANs.

Creating an interface on an ATM port assigns a network IP address and submask on that port, and assigns it to a specified VC (VPI/VCI pair). Since a VC is a connection in the ATM Layer only, creating an interface for an ATM port is necessary to establish a connection in the IP network layer.

The following example illustrates how you can use routing on an ATM module to accommodate different requirements from two client groups using only one ATM physical connection. This is accomplished by setting up two VCs on the ATM port, each with its own service profiles and bandwidth.

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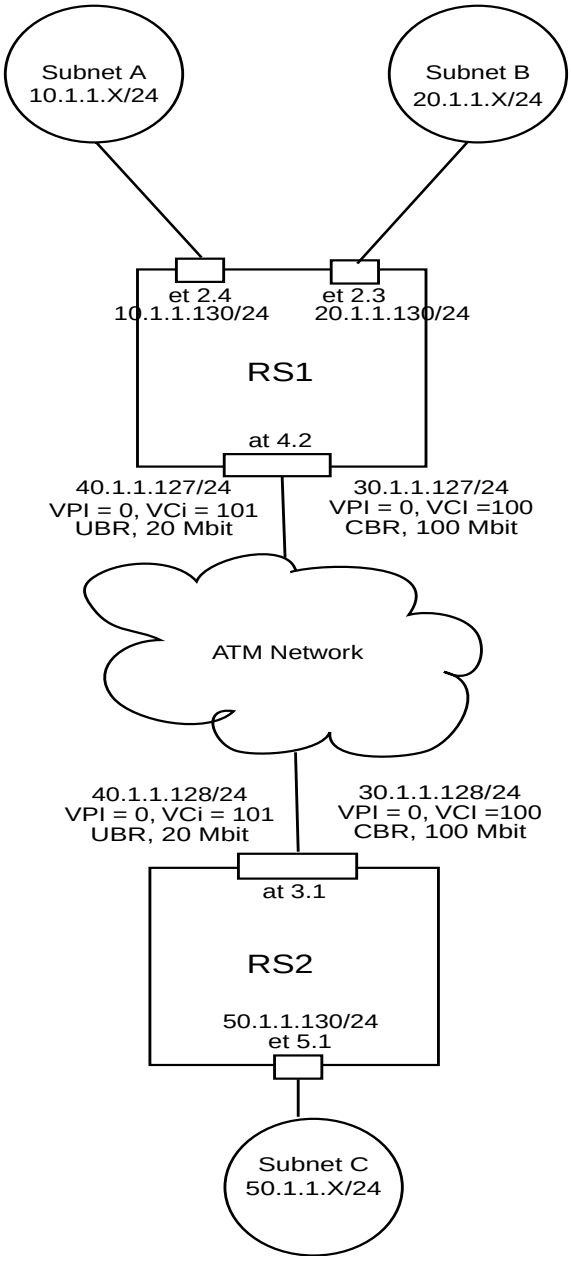

Figure 8-3 Routing ATM traffic configuration example

Suppose you are a network administrator in charge of managing a network with two client groups: Subnet A and Subnet B. These two client groups have very different bandwidth needs and requirements for their respective users. Subnet A consists of users who need access to a high bandwidth connection, able to support video conferencing. Subnet B consists of users who require less stringent requirements and are mainly concerned with email and server backup type traffic.

Configuration is done in two steps. The first step is to configure the network for traffic from Subnet A and Subnet B to Subnet C. The second step is to configure the network for traffic from Subnet C to Subnet A and Subnet B and assign ACLs to place subnets on correct VCLs. Now all traffic between Subnet A and Subnet C travels over the 20 Mbit VCL, while all traffic between Subnet B and Subnet C travels over the 100 Mbit VCL.

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Following is the configuration for RS1:

```
Configure an interface on each ethernet port.
rs1(config)# interface create ip subnetA address-netmask 10.1.1.130/24
port et.2.4 up
rs1(config)# interface create ip subnetB address-netmask 20.1.1.130/24
port et.2.3 up

Create the virtual channels.
rs1(config)# atm create vcl port at.4.2.0.100
rs1(config)# atm create vcl port at.4.2.0.101

Configure an interface on each ATM port.
rs1(config)# interface create ip ubrservice address-netmask
40.1.1.127/24 peer-address 40.1.1.128/24 port at.4.2.0.101 up
rs1(config)# interface create ip cbrservice address-netmask
30.1.1.127/24 peer-address 30.1.1.128/24 port at.4.2.0.100 up

Define the ATM service profiles.
rs1(config)# atm define service ubrservice srv-cat ubr pcr-kbits 20000
rs1(config)# atm define service cbrservice srv-cat cbr pcr-kbits 100000

Apply the ATM service profiles.
rs1(config)# atm apply service ubrservice port at.4.2.0.101
rs1(config)# atm apply service cbrservice port at.4.2.0.100

Create IP ACLs.
RS1(config)# acl subnetAtoCacl permit 10.1.1.0/24 any any any
rs1(config)# acl subnetBtoCacl permit 20.1.1.0/24 any any any

Specify a gateway for each IP policy.
rs1(config)# ip-policy subnetAtoCpolicy permit acl subnetAtoCacl
next-hop-list 40.1.1.128/24 action policy-first
rs1(config)# ip-policy subnetBtoCpolicy permit acl subnetBtoCacl
next-hop-list 30.1.1.128/24 action policy-first

Apply the IP policies to the ethernet ports.
rs1(config)# ip-policy subnetAtoCpolicy apply interface subnetA
rs1(config)# ip-policy subnetBtoCpolicy apply interface subnetB
```


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Following is the configuration for RS2:

```
Configure an interface on the ethernet port that leads to Subnet C.
rs2(config)# interface create ip subnetC address-netmask 50.1.1.130/24
port et.5.1 up

Create the virtual channels on port at.4.2.
rs2(config)# atm create vcl port at.3.1.0.100
rs2(config)# atm create vcl port at.3.1.0.101

Configure an interface for each VC.
rs2(config)# interface create ip ubrservice address-netmask
40.1.1.128/24 peer-address 40.1.1.127/24 port at.3.1.0.101 up
rs2(config)# interface create ip cbrservice address-netmask
30.1.1.128/24 peer-address 30.1.1.127/24 port at.3.1.0.100 up

Define the ATM service profiles.
rs2(config)# atm define service ubrservice srv-cat ubr pcr-kbits 20000
rs2(config)# atm define service cbrservice srv-cat cbr pcr-kbits 100000

Apply the ATM service profiles.
rs2(config)# atm apply service ubrservice port at.3.1.0.101
rs2(config)# atm apply service cbrservice port at.3.1.0.100

For traffic from subnet C to subnets A and B, create IP ACLs.
rs2(config)# acl subnetCtoAacl permit 50.1.1.0/24 10.1.1.0/24 any any
rs2(config)# acl subnetCtoBacl permit 50.1.1.0/24 20.1.1.0/24 any any

Specify a gateway for each IP policy.
rs2(config)# ip-policy subnetCtoApolicy permit acl subnetCtoAacl
next-hop-list 40.1.1.127/24 action policy-first
rs2(config)# ip-policy subnetCtoBpolicy permit acl subnetCtoBacl
next-hop-list 30.1.1.127/24 action policy-first

Apply IP policies to the Ethernet ports.
rs2(config)# ip-policy subnetCtoApolicy apply interface subnetC
rs2(config)# ip-policy subnetCtoBpolicy apply interface subnetC
```

8.6.1 Peer Address Mapping

You can map a peer address to a specific virtual channel. This allows you to set the destination address for a virtual channel using the **`atm set peer-addr`** command. This way, a virtual channel can be dedicated to handle traffic between two specific devices.

Mapped addresses are useful when you do not want to specify the peer address for the ATM port using the **`interface create`** command. This would be the case if the interface is created for a VLAN and there are many peer addresses on the VLAN. If any of the peers on the VLAN do not support InArp or IPCP/IPXCP, then a mapped address must be configured to determine the destination address.

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Note Specify a peer address if the RS is handling VC-mux encapsulated traffic.

In the following example, a connection is established between a video server and three video clients (Video Client 1, Video Client 2, and Video Client 3). The video server routes data through the RS to the video clients. Traffic passes to the video clients through three separate virtual channels. Each virtual channel has a unique service profile.

In addition, the RS is transmitting VC-mux encapsulation traffic. Peer address mapping is used to associate a particular destination address with each VC. This allows the RS to route traffic to a specific client without multicasting to every virtual channel.

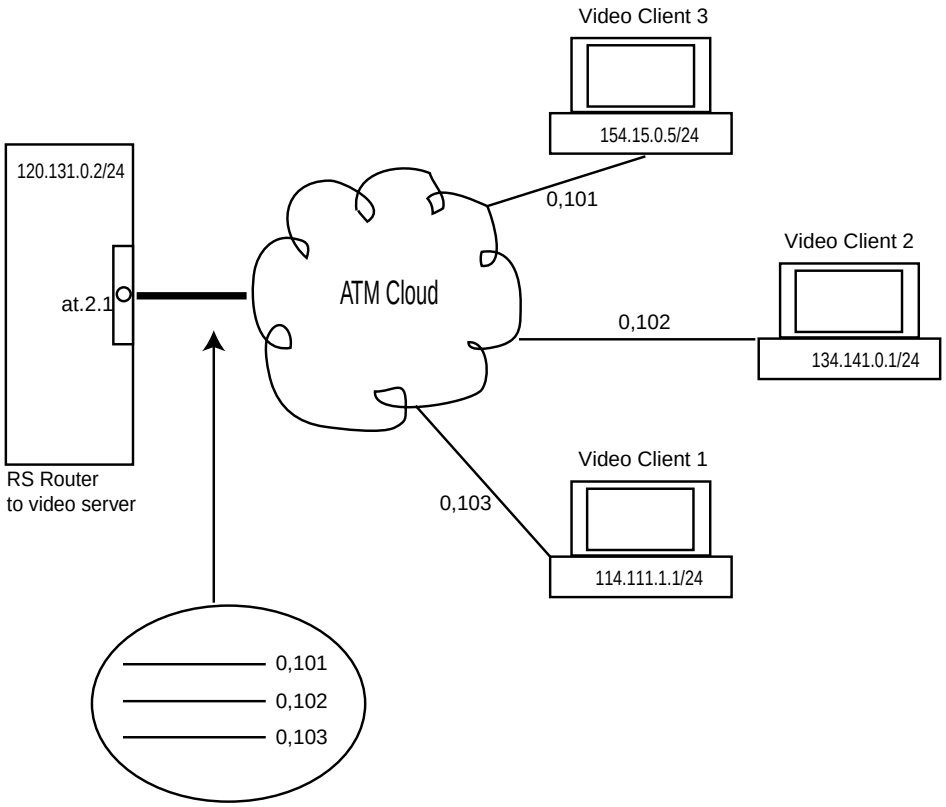

Figure 8-4 Peer address mapping configuration example

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Following is the configuration for the RS:

```
Create the virtual channels that will connect to each video client.
rs(config)# atm create vcl port at.2.1.0.101
rs(config)# atm create vcl port at.2.1.0.102
rs(config)# atm create vcl port at.2.1.0.103

Create a VLAN called 'video' which supports all protocols.
rs(config)# vlan create video ip id 20

Add the VCs to the VLAN.
rs(config)# vlan add ports at.2.1.0.101 to video
rs(config)# vlan add ports at.2.1.0.102 to video
rs(config)# vlan add ports at.2.1.0.103 to video

Configure the interface and associate it with the VLAN.
rs(config)# interface create ip atm-video address-netmask
120.131.0.2/24 vlan video

Assign a peer address to each VC (for VC-mux encapsulation traffic).
rs(config)# atm set peer-addr port at.2.1.0.101 ip-address
114.111.1.1/24
rs(config)# atm set peer-addr port at.2.1.0.102 ip-address
134.141.0.1/24
rs(config)# atm set peer-addr port at.2.1.0.103 ip-address
154.15.0.5/24
```

8.7 CONFIGURING PPP (OC-12)

You can configure a point-to-point protocol (PPP) connection between a VC on the OC-12 line card on the RS and another device. When you define a service profile for the VC, you should specify **ppp** for the traffic parameter. You can also do the following:

- specify parameters for the transmission of Configure-NAK, Terminate-Nak, and Configure-Request packets
- enable/disable Magic Numbers
- enable/disable the transmission of Echo Request and Reply packets
- set PPP authentication

For a complete description of PPP, refer to Chapter 30, *"WAN Configuration."*

Note This feature is *not* valid for the ATM multi-rate line card.

The following example illustrates how to configure a PPP connection between a DSL modem and the RS. It uses CHAP authentication on an AAA server for the PPP connection.

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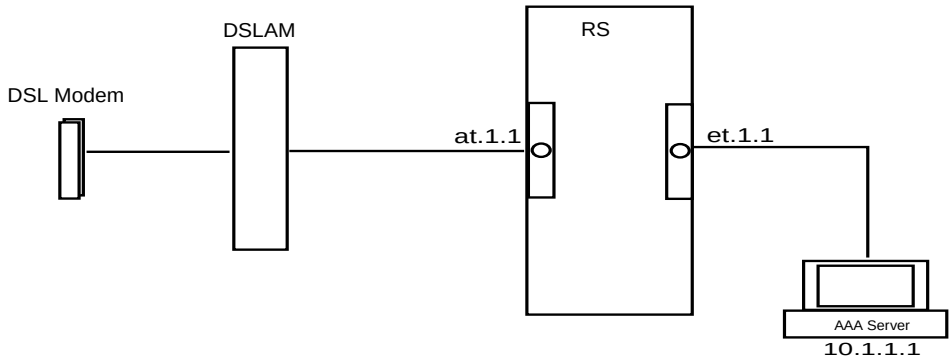

Figure 8-5 PPP configuration example

Following is the configuration for the RS:

Create a virtual channel for the PPP connection.
```
rs(config)# atm create vcl port at.1.1.0.200
```

Define the PPP service profile.
```
rs(config)# atm define service cm1 srv-cat rt-vbr encaps vc-mux traffic
ppp ppp-auth chap
```

Apply the service profile to the VC.
```
atm apply service cm1 port at.2.1.0.200
```

For this configuration example, configure RADIUS for PPP authentication on an AAA server.
```
rs(config)# radius set key secretpassword
```

Identify the AAA server.
```
rs(config)# radius set server 10.1.1.1
```

Enable RADIUS authentication.
```
rs(config)# radius enable
```


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To display PPP (Point-to-Point Protocol) statistics for an ATM OC-12 line card, use the **atm show ppp** command as shown in the following example:

```
rs# atm show ppp port all
-----------------------------------------------
at.5.1:
Total LCP            (Enabled/Up): 0/0
Total IP             (Enabled/Up): 0/0
Total IPX            (Enabled/Up): 0/0
Total Bridging       (Enabled/Up): 0/0
Total Authentication (Enabled/Up): 0/0

    Virtual Path Identifier:        1
    Virtual Channel Identifier:     100
    LCP  Status:              Disabled/Down
    IP  Status:               Disabled/Down
    IPX  Status:              Disabled/Down
    Bridging  Status:         Disabled/Down
    Authentication  Status:   Disabled/Down
    Authentication  Type:     None/None
```


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9 PACKET-OVER-SONET CONFIGURATION GUIDE

This chapter explains how to configure and monitor Packet-over-SONET (PoS) on the RS. See the **sonet** commands section of the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a description of each command.

PoS requires installation of the OC-3c or OC-12c PoS line cards in an RS 8000 or an RS 8600. The OC-3c line card has four PoS ports, while the OC-12c line card has two PoS ports. You must use the "so" prefix for PoS interface ports. For example, you would specify the first PoS port located at router slot 13, port 1 as "so.13.1."

By default, PoS ports are set for point-to-point protocol (PPP) encapsulation. The only other supported encapsulation type is bridged Ethernet over PPP.

Note While PoS ports use PPP encapsulation, other PPP characteristics such as service profiles, encryption, compression, and MLP bundles are not supported for PoS ports.

By default, PoS ports are configured to receive a maximum transmission unit (MTU) size of 1522 octets. The actual MTU size used for transmissions over a PoS link is a result of PPP negotiation. For transmission of "jumbo frames" (MTUs up to 65535 octets), you can increase the MTU size of the PoS port. The MTU must be set at the port level.

9.1 CONFIGURING IP INTERFACES FOR POS LINKS

Configuring IP interfaces for PoS links is generally the same as for WANs and for LANs. You assign an IP address to each interface and define routing mechanisms such as OSPF or RIP as with any IP network. You can configure the IP interface on the physical port or you can configure the interface as part of a VLAN for PoS links. You can also configure multiple IP addresses for each interface, as described in Section 11.2, *"Configuring IP Interfaces and Parameters"*.

When creating the IP interface for a PoS link, you can either specify the peer address if it is known (*static* address), or allow the peer address to be automatically discovered via IPCP negotiation (*dynamic* address). If the peer address is specified, any address supplied by the peer during IPCP negotiation is ignored.

IP interfaces for PoS links can have primary and secondary IP addresses. The primary addresses may be either dynamic or static, but the secondary address must be static. This is because only the primary addresses of both the local and peer devices are exchanged during IP Control Protocol (IPCP) negotiation.

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Source filtering and ACLs can be applied to an IP interface for a PoS link. Unlike WAN ports, the applied filter or ACL presents no limitation. Different filters can be configured on different PoS ports.

9.2 CONFIGURING PACKET-OVER-SONET LINKS

To configure a Packet-over-SONET link:

1. On the RS, assign an interface to the PoS port to which you will connect via fiber cable in a point-to-point link. Assign an IP address and netmask to the interface. If possible, determine the peer address of the interface at the other end of the point-to-point link. In the following example, the port so.13.1 on the RS will be associated with the interface pos11:

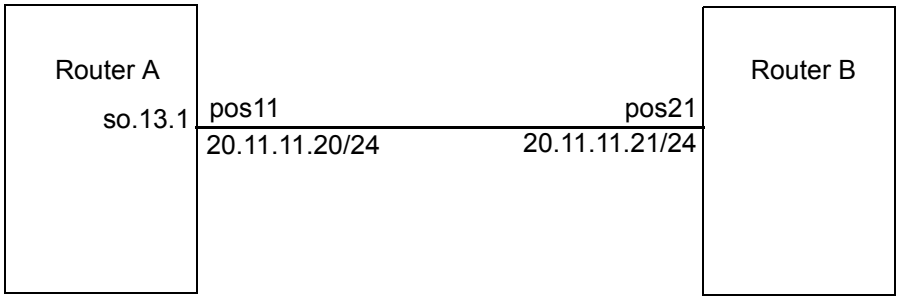

Figure 9-1 Configuring PoS links

2. Create a PPP interface with the **`interface create`** command, specifying the IP address and netmask for the interface on the RS:

```
rs(config)# interface create ip pos11 address-netmask 20.11.11.20/24
port so.13.1
```

When you create the point-to-point interface as shown above, the RS creates an implicit VLAN called "SYS_L3_<*interface-name*>." In the above example, the RS creates the VLAN 'SYS_L3_pos11.'

3. Specify the peer address of the other end of the connection. This is optional.
4. If you want to increase the MTU size on a port, specify the parameter **`mtu`** with the **`port set`** command and define a value up to 65535 (octets). See Section 11.3, *"Configuring Jumbo Frames"* for more information.
5. Specify the bit error rate thresholds, if necessary. For more information, see Section 9.4, *"Specifying Bit Error Rate Thresholds"*
6. Modify any other PoS operating parameters, as needed. The following table lists the operating parameters that you can modify and the configuration commands that you use.

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Table 9-1 PoS optional operating parameters

Parameter	Default Value	Configuration Command
Framing	SONET	**sonet set** <*port*> **framing sdh|sonet**
Loopback	Disabled	**sonet set** <*port*> **loopback**
Path tracing	(none)	**sonet set** <*port*> **pathtrace**
Circuit identifier	(none)	**sonet set** <*port*> **circuit-id**
Frame Check Sequence	32-bit	**sonet set** <*port*> **fcs-16-bit**
Scrambling	Enabled	**sonet set** <*port*> **no-scramble**

9.3 CONFIGURING AUTOMATIC PROTECTION SWITCHING

Automatic protection switching (APS) provides a mechanism to support redundant transmission circuits between SONET devices. The RS supports the following APS features:

- Linear network topology. Ring topologies are not supported.
- 1+1 switching. Each working line is protected by one protecting line and the same signal is transmitted on both the working and protecting lines. The two transmission copies that arrive at the receiving end are compared, and the best copy is used. If there is a line failure or line degradation, the end node switches the connection over to the protecting line.

Note In APS terminology, *bridge* means to transmit identical traffic on both the working and protecting lines, while *switch* means to select traffic from either the protecting line or the working line.

- Unidirectional switching, where one set of line terminating equipment (LTE) can switch the line independent of the other LTE. Bidirectional switching (where both sets of LTEs perform a coordinated switch) is not supported.
- Revertive switching. You can enable automatic switchover from the protecting line to the working line after the working line becomes available.

If the working circuit is disrupted or the bit error rates on the working circuit exceed the configured thresholds, traffic is automatically switched over to the protecting circuit. Any physical or logical characteristics configured for the working port are automatically applied to the protecting port. This includes the IP address and netmask configured for the interface, spanning tree protocol (STP), per-VLAN spanning tree (PVST), etc. Therefore, there is no need to configure the protecting port separately. Any command applied to the PoS working port is mirrored onto the protecting port automatically.

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9.3.1 Configuring Working and Protecting Ports

APS on the RS requires configuration of a working port and a corresponding protecting port. You can configure any number of pairs of PoS ports for APS. The limit is the number of PoS ports on the RS. If one module should go down, the remaining ports on other modules will remain operational.

Note The protecting port can be on the same slot or located on a different slot as the working port, but they must reside on the *same* RS. You *cannot* configure APS operation for working and protecting ports on two *different* RS's.

The working and protecting port must support identical optical carrier rates. For example, if the working port operates at OC-12, the protecting port must also be OC-12.

The protecting port must not have been used in an active configuration. After being configured as the protecting port, it cannot be explicitly configured except for the APS properties. The protecting port automatically inherits the configuration of the working port.

To configure a working and a protecting PoS port, enter the following command in Configure mode:

Configure working and protecting PoS ports.	**sonet set** <*working-port*> **protection 1+1 protected-by** <*protecting-port*>

To manage the working and protecting PoS interfaces, enter the following commands in Configure mode:

Prevent a working port from switching to a protecting port. This command can only be applied to a port configured as a protecting port.	**sonet set** <*port*> **protection-switch lockoutprot**
Force a switch to the specified port. This command can be applied to either the working or protecting port.	**sonet set** <*port*> **protection-switch forced**
Manually switch the line to the specified port. This command can be applied to either the working or protecting port.	**sonet set** <*port*> **protection-switch manual**

Note You can only specify one option, **lockoutprot**, **forced** or **manual**, for a port. Also, an option can be applied to *either* the working port or the protecting port, but not *both* working and protecting ports at the same time.

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To return the circuit to the working interface after the working interface becomes available, enter the following commands in Configure mode:

Enable automatic switchover from the protecting interface to the working interface after the working interface becomes available. This command can only be applied to a protecting port.	**sonet set** *<port>* **revertive on|off**
Sets the number of minutes after the working interface becomes available that automatic switchover from the protecting interface to the working interface takes place. The default value is 5 minutes.	**sonet set** *<port>* **WTR-timer** *<minutes>*

9.4 SPECIFYING BIT ERROR RATE THRESHOLDS

If the bit error rate (BER) on the working line exceeds that of the configured thresholds, the receiver automatically switches over to the protecting line.

BER is calculated with the following:

BER = errored bits received/total bits received

The default BER thresholds are:

- Signal degrade BER threshold of 10^{-6} (1 out of 1,000,000 bits transmitted is in error). Signal degrade is associated with a "soft" failure. Signal degrade is determined when the BER exceeds the configured rate.
- Signal failure BER threshold of 10^{-3} (1 out of 1,000 bits transmitted is in error). Signal failure is associated with a "hard" failure. Signal fail is determined when any of the following conditions are detected: loss of signal (LOS), loss of frame (LOF), line alarm indication bridge and selector signal (AIS-L), or the BER threshold exceeds the configured rate.

To specify different BER thresholds, enter the following commands in Enable mode:

Specify signal degrade BER threshold.	**sonet set** *<port>* **sd-ber** *<number>*
Specify signal failure BER threshold.	**sonet set** *<port>* **sf-ber** *<number>*

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9.5 MONITORING POS PORTS

To display PoS port configuration information, enter one of the following commands in Enable mode:

Show framing status, line type, and circuit ID of the optical link.	**sonet show medium** *<port list>*
Show working or protecting line, direction, and switch status.	**sonet show aps** *<port list>*
Show received path trace.	**sonet show pathtrace** *<port list>*
Show loopback status.	**sonet show loopback** *<port list>*
Show alarms and errors on SONET ports.	**sonet show alarms** *<port list>*

The following table describes additional monitoring commands for IP interfaces for PoS links, designed to be used in Enable mode:

Display bridge NCP statistics for specified PoS port.	**ppp show stats ports** *<port name>* **bridge-ncp**
Display IP NCP statistics for specified PoS port.	**ppp show stats ports** *<port name>* **ip-ncp**
Display link-status statistics for specified PoS port.	**ppp show stats ports** *<port name>* **link-status**
Display summary information for specified PoS port.	**ppp show stats ports** *<port name>* **summary**

9.6 EXAMPLE CONFIGURATIONS

This section shows example configurations for PoS links.

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9.6.1 APS PoS Links Between RS's

The following example shows APS PoS links between two RS's, router A and router B.

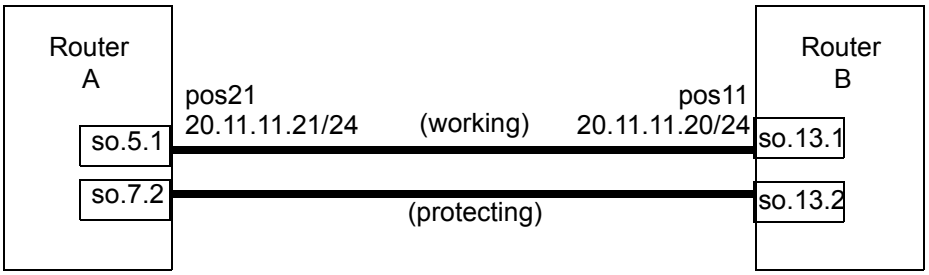

Figure 9-2 Automatic protection switching between two routers

The following is the configuration for router A:

```
interface create ip pos21 address-netmask 20.11.11.21/24 port so.5.1
sonet set so.7.1 protection 1+1 protected-by so.7.2
```

The following is the configuration for router B:

```
interface create ip pos11 address-netmask 20.11.11.20/24 port so.13.1
sonet set so.13.1 protection 1+1 protected-by so.13.2
```

9.6.2 PoS Link Between the RS and a Cisco Router

The following example shows a PoS link between an RS, router A, and a Cisco 12000 series Gigabit Switch Router, router B.

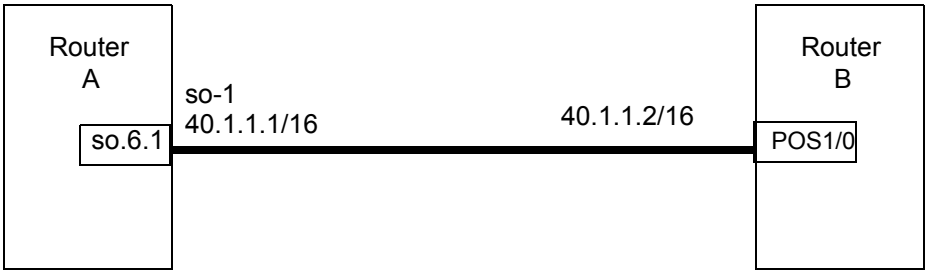

Figure 9-3 PoS link between the RS and a CISCO router

The following is the configuration for router A:

```
interface create ip so-1 address-netmask 40.1.1.1/16 port so.6.1
```


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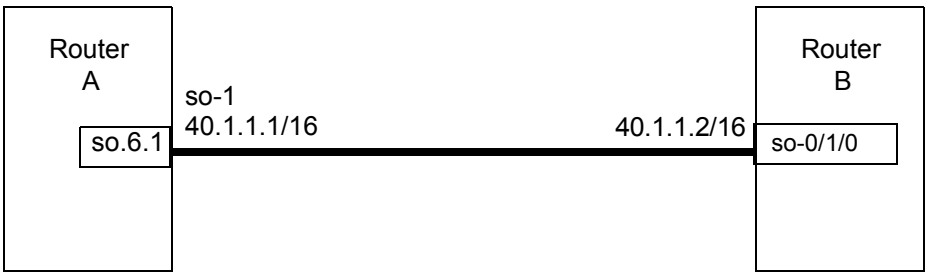
The following is the configuration for router B:

```
interface POS1/0
 ip address 40.1.1.2 255.255.0.0
 no ip directed-broadcast
 encapsulation ppp
 crc 32
 pos scramble-atm
 pos flag c2 22
```

9.6.3 PoS Link Between the RS and a Juniper Router

The following example shows a PoS link between an RS, router A, and a Juniper router, router B.



The following is the configuration for router A:

```
interface create ip so-1 address-netmask 40.1.1.1/16 port so.6.1 peer-address
40.1.1.2
```

Note When you create an IP interface on the RS for a PoS link with a Juniper router, you *must* specify the **peer-address** parameter. Otherwise, IP Control Protocol (IPCP) negotiations will fail.

The following is the configuration for router B:

```
root# set interfaces so-0/1/0 unit 0 family inet address 40.1.1.2/16
root# set interfaces so-0/1/0 encapsulation ppp
root# set interfaces so-0/1/0 sonet-options fcs 32
```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9.6.4 Bridging and Routing Traffic Over a PoS Link

The following example shows how to configure a VLAN ‘v1’ that includes the PoS ports on two connected RS’s, router A and router B. Bridged or routed traffic is transmitted over the PoS link.

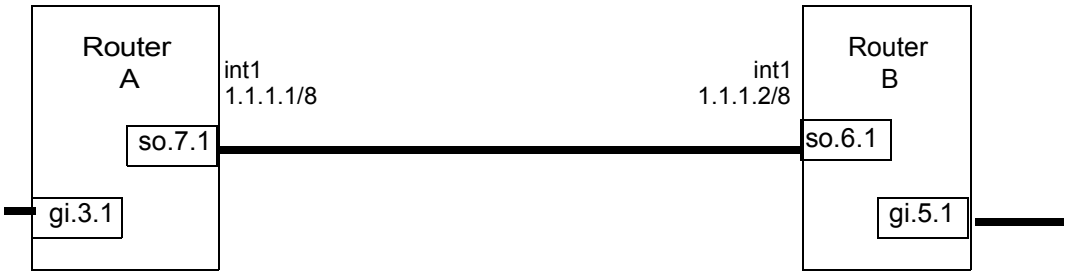


Figure 9-4 VLAN with PoS links

The following is the configuration for router A:

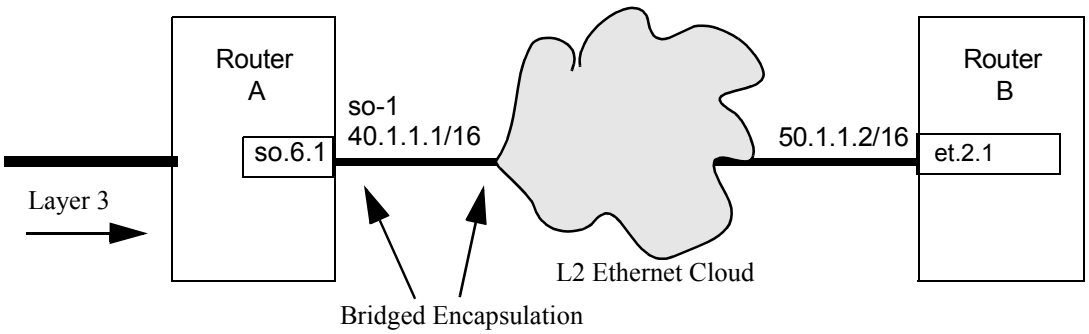
```
port set so.7.1 mtu 65535
stp enable port so.7.1
vlan create v1 port-based id 10
vlan add ports so.7.1,gi.3.1 to v1
interface create ip int1 address-netmask 1.1.1.1/8 vlan v1
```

The following is the configuration for router B:

```
port set so.6.1 mtu 65535
stp enable port so.6.1
vlan create v1 port-based id 10
vlan add ports so.6.1,gi.5.1 to v1
interface create ip int1 address-netmask 1.1.1.2/8 vlan v1
```

9.6.5 PoS Link Through a Layer 2 Cloud

The following example shows a PoS link between Router A and Router B. Both routers are connected by a PPP connection that goes through a L2 cloud, a Layer 2 switch.



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The packets forwarded across the L2 Ethernet cloud must contain certain Ethernet MAC headers. Otherwise, the packets will be dropped at the edge of the cloud, in this case a L2 switch.

To encapsulate an Ethernet MAC header in the PPP frames, the port ‘so.6.1’ PoS port and its peer at the edge of the cloud must be set in the Ethernet bridged encapsulation mode.

To enable Ethernet bridged encapsulation on port ‘so.6.1’ for PPP traffic:

```
ppp set ppp-encaps-bgd ports so.6.1
```

Note PoS ports that will be trunk ports (i.e., support the 802.1q protocol) *must* be configured for bridged encapsulation. See the documentation for the **`ppp set ppp-encaps-bgd`** command in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

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10 DHCP CONFIGURATION GUIDE

The Dynamic Host Configuration Protocol (DHCP) server on the RS provides dynamic address assignment and configuration to DHCP capable end-user systems, such as Windows 95/98/NT and Apple Macintosh systems. You can configure the server to provide a dynamic IP address from a pre-allocated pool of IP addresses or a static IP address. You can also configure parameters for use by the clients, such as default gateway and network masks, and system-specific parameters, such as NetBIOS Name Server and NetBIOS node type of the client.

The amount of time that a particular IP address is valid for a system is called a *lease*. The RS maintains a *lease database* which contains information about each assigned IP address, the MAC address to which it is assigned, the lease expiration, and whether the address assignment is dynamic or static. The DHCP lease database is stored in flash memory and can be backed up on a remote TFTP or RCP server. You can configure the intervals at which updates to the lease database (and backup) are done. Upon system reboot, the lease database will be loaded either from flash memory or from the TFTP or RCP server.

Note The RS DHCP server is not designed to work as the primary DHCP server in an enterprise environment with hundreds or thousands of clients that are constantly seeking IP address assignment or reassignment. A standalone DHCP server with a redundant backup server may be more suitable for this enterprise environment.

10.1 CONFIGURING DHCP

By default, the DHCP server is not enabled on the RS. You can selectively enable DHCP service on particular interfaces and not others. To enable DHCP service on an interface, you must first define a DHCP *scope*. A scope consists of a pool of IP addresses and a set of parameters for a DHCP client. The parameters are used by the client to configure its network environment, for example, the default gateway and DNS domain name.

To configure DHCP on the RS, you must configure an IP address pool, client parameters, and optional static IP address for a specified scope. Where several subnets are accessed through a single port, you can also define multiple scopes on the same interface and group the scopes together into a “superscope.”

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10.1.1 Configuring an IP Address Pool

To define a pool of IP addresses that the DHCP server can assign to a client, enter the following command in Configure mode:

Define pool of IP addresses to be used by clients.	**dhcp** <*scope*> **define pool** <*ip-range*>

10.1.2 Configuring Client Parameters

You can configure the client parameters shown in the table below.

Table 10-1 Client parameters

Parameter	Value
address-mask	Address/netmask of the scope's subnet (This parameter is *required* and must be defined *before* any other client parameters are specified.)
broadcast	Broadcast address
bootfile	Client boot file name
dns-domain	DNS domain name
dns-server	IP address of DNS server
gateway	IP address of default gateway
lease-time	Amount of time the assigned IP address is valid for the system
netbios-name-server	IP address of NetBIOS Name Server (WINS server)
netbios-node-type	NetBIOS node type of the client
netbios-scope	NetBIOS scope of the client

To define the parameters that the DHCP server gives the clients, enter the following command in Configure mode:

Define client parameters.	**dhcp** <*scope*> **define parameters** <*parameter*> <*value*>...

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10.1.3 Configuring a Static IP Address

To define a static IP address that the DHCP server can assign to a client with a specific MAC address, enter the following command in Configure mode:

Define static IP address for a particular MAC address.	**dhcp** <*scope*> **define static-ip** <*ipaddr*> **mac-address** <*macaddr*> [<*parameter*> <*value*>...]

10.1.4 Grouping Scopes with a Common Interface

You can apply several scopes to the same physical interface. For example, scopes can define address pools on different subnets that all are accessed through the same RS port. In this case, scopes that use the same interface must be grouped together into a "superscope."

To attach a scope to a superscope, enter the following command in Configure mode:

Attach a scope to a superscope.	**dhcp** <*scope*> **attach superscope** <*name*>

10.1.5 Configuring DHCP Server Parameters

You can configure several "global" parameters that affect the behavior of the DHCP server itself.

To configure global DHCP server parameters, enter the following commands in Configure mode:

Specify a remote location to back up the lease database.	**dhcp global set lease-database** <*url*>
Specify the intervals at which the lease database is updated.	**dhcp global set commit-interval** <*hours*>

10.2 UPDATING THE LEASE DATABASE

After each client transaction, the DHCP server does not immediately update the information in the lease database. Lease update information is stored in flash memory and flushed to the database at certain intervals. You can use the **dhcp global set commit-interval** command to specify this interval; the default is one hour.

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To force the DHCP server to immediately update its lease database, enter the following command in Enable mode:

Force the server to update its lease database.	**dhcp flush**

10.3 MONITORING THE DHCP SERVER

To display information from the lease database:

Show lease database information.	**dhcp show binding [active|expired|static]**

To display the number of allocated bindings for the DHCP server and the maximum number allowed::

Show the number of allocated bindings for the DHCP server.	**dhcp show num-clients**

10.4 DHCP CONFIGURATION EXAMPLES

The following configuration describes DHCP configuration for a simple network with just one interface on which DHCP service is enabled to provide both dynamic and static IP addresses.

1. Create an IP VLAN called ‘client_vlan’.

```
vlan create client_vlan ip
```

2. Add all Fast Ethernet ports in the RS to the VLAN ‘client_vlan’.

```
vlan add port et.*.* to client_vlan
```

3. Create an IP interface called ‘clients’ with the address 10.1.1.1 for the VLAN ‘client_vlan’.

```
interface create ip clients address-netmask 10.1.1.1./16 vlan
client_vlan
```


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4. Define DHCP network parameters for the scope ‘scope1’.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 lease-time 24 dns-domain acme.com dns-server 10.2.45.67
netbios-name-server 10.1.55.60
```

5. Define an IP address pool for addresses 10.1.1.10 through 10.1.1.20.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

6. Define another IP address pool for addresses 10.1.1.40 through 10.1.1.50.

```
dhcp scope1 define pool 10.1.1.40-10.1.1.50
```

7. Define a static IP address for 10.1.7.5.

```
dhcp scope1 define static-ip 10.1.7.5 mac-address 08:00:20:11:22:33
```

8. Define another static IP address for 10.1.7.7. and give it a specific gateway address of 10.1.1.2.

```
dhcp scope1 define static-ip 10.1.7.7 mac-address
08:00:20:aa:bb:cc:dd gateway 10.1.1.2
```

9. Specify a remote lease database on the TFTP server 10.1.89.88.

```
dhcp global set lease-database tftp://10.1.89.88/lease.db
```

10. Specify a database update interval of every 15 minutes.

```
dhcp global set commit-interval 15
```

10.5 CONFIGURING SECONDARY SUBNETS

In some network environments, multiple logical subnets can be imposed on a single physical segment. These logical subnets are sometimes referred to as “secondary subnets” or “secondary networks.” For these environments, the DHCP server may need to give out addresses on different subnets. The DNS server, DNS domain, and WINS server may be the same for clients on different secondary subnets, however, the default gateway will most likely be different since it must be a router on the client’s local subnet.

The following example shows a simple configuration to support secondary subnets 10.1.x.x and 10.2.x.x.

1. Define the network parameters for ‘scope1’ with the default gateway 10.1.1.1.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 dns-domain acme.com dns-server 10.1.44.55
```


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2. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

3. Define the network parameters for ‘scope2’ with the default gateway 10.2.1.1.

```
dhcp scope2 define parameters address-netmask 10.2.0.0/16 gateway
10.2.1.1 dns-domain acme.com dns-server 10.1.77.88
```

4. Define the address pool for ‘scope2’.

```
dhcp scope2 define pool 10.2.1.40-10.2.1.50
```

5. Create a superscope ‘super1’ that includes ‘scope1’.

```
dhcp scope1 attach superscope super1
```

6. Include ‘scope2’ in the superscope ‘super1’.

```
dhcp scope2 attach superscope super1
```

Since there are multiple pools of IP addresses, the pool associated with ‘scope1’ is used first since ‘scope1’ is applied to the interface before ‘scope2’. Clients that are given an address from ‘scope1’ will also be given parameters from ‘scope1,’ which includes the default gateway 10.1.1.1 that resides on the 10.1.x.x subnet. When all the addresses for ‘scope1’ are assigned, the server will start giving out addresses from ‘scope2’ which will include the default gateway parameter 10.2.1.1 on subnet 10.2.x.x.

10.6 SECONDARY SUBNETS AND DIRECTLY-CONNECTED CLIENTS

A directly-connected client is a system that resides on the same physical network as the DHCP server and does not have to go through a router or relay agent to communicate with the server. If you configure the DHCP server on the RS to service directly-connected clients on a secondary subnet, you must configure the secondary subnet using the **`interface add ip`** command. The **`interface add ip`** command configures a secondary address for an interface that was previously created with the **`interface create ip`** command.

The following example shows a simple configuration to support directly-connected clients on a secondary subnet.

1. Create an interface ‘clients’ with the primary address 10.1.1.1.

```
interface create ip clients address-mask 10.1.1.1/16 port et.1.1
```

2. Assign a secondary address 10.2.1.1 to the interface ‘clients’.

```
interface add ip clients address-mask 10.2.1.1/16
```


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3. Define the network parameters for ‘scope1’ with the default gateway 10.1.1.1.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 dns-domain acme.com dns-server 10.1.44.55
```

4. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

5. Define the network parameters for ‘scope2’ with the default gateway 10.2.1.1.

```
dhcp scope2 define parameters address-netmask 10.2.0.0/16 gateway
10.2.1.1 dns-domain acme.com dns-server 10.1.77.88
```

6. Define the address pool for ‘scope2’.

```
dhcp scope2 define pool 10.2.1.40-10.2.1.50
```

7. Create a superscope ‘super1’ that includes ‘scope1’.

```
dhcp scope1 attach superscope super1
```

8. Include ‘scope2’ in the superscope ‘super1’.

```
dhcp scope2 attach superscope super1
```

For clients on the secondary subnet, the default gateway is 10.2.1.1, which is also the secondary address for the interface ‘clients’.

10.7 INTERACTING WITH RELAY AGENTS

For clients that are not directly connected to the DHCP server, a relay agent (typically a router) is needed to communicate between the client and the server. The relay agent is usually only needed during the initial leasing of an IP address. Once the client obtains an IP address and can connect to the network, the renewal of the lease is performed between the client and server without the help of the relay agent.

The default gateway for the client must be capable of reaching the RS’s DHCP server. The RS must also be capable of reaching the client’s network. The route must be configured (with static routes, for example) or learned (with RIP or OSPF, for example) so that the DHCP server can reach the client.

The following example shows a simple configuration to support clients across a relay agent.

1. Create an interface ‘clients’ with the primary address 10.1.1.1.

```
interface create ip clients address-mask 10.1.1.1/16 port et.3.3
```


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2. Define a static route to the 10.5.x.x. subnet using the gateway 10.1.7.10 which tells the DHCP server how to send packets to the client on the 10.5.x.x subnet.

```
ip add route 10.5.0.0/16 gateway 10.1.7.10
```

3. Define the network parameters for ‘scope1’ with the default gateway 10.5.1.1 (the relay agent for the client).

```
dhcp scope1 define parameters address-netmask 10.5.0.0/16 gateway
10.5.1.1 dns-domain acme.com
```

4. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.5.1.10-10.5.1.20
```


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11 IP ROUTING CONFIGURATION GUIDE

The RS supports standards-based TCP, UDP, and IP. This chapter describes how to configure IP interfaces and general non-protocol-specific routing parameters.

11.1 IP ROUTING PROTOCOLS

The RS supports standards-based unicast and multicast routing. Unicast routing protocol support includes Interior Gateway Protocols and Exterior Gateway Protocols. Multicast routing protocols are used to determine how multicast data is transferred in a routed environment.

11.1.1 Unicast Routing Protocols

Interior Gateway Protocols are used for routing networks that are within an “autonomous system,” a network of relatively limited size. All IP interior gateway protocols must be specified with a list of associated networks before routing activities can begin. A routing process listens to updates from other routers on these networks and broadcasts its own routing information on those same networks. The RS supports the following Interior Gateway Protocols:

- Routing Information Protocol (RIP) Version 1, 2 (RFC 1058, 1723). Configuring RIP for the RS is described in Chapter 13, *"RIP Configuration Guide."*
- Open Shortest Path First (OSPF) Version 2 (RFC 1583). Configuring OSPF for the RS is described in Chapter 14, *"OSPF Configuration Guide."*
- Intermediate System-Intermediate System (IS-IS) (RFC 1142). Configuring IS-IS for the RS is described in Chapter 15, *"IS-IS Configuration Guide."*.

Exterior Gateway Protocols are used to transfer information between different “autonomous systems”. The RS supports the following Exterior Gateway Protocol:

- Border Gateway Protocol (BGP) Version 3, 4 (RFC 1267, 1771). Configuring BGP for the RS is described in Chapter 16, *"BGP Configuration Guide."*

11.1.2 Multicast Routing Protocols

IP multicasting allows a host to send traffic to a subset of all hosts. These hosts subscribe to group membership, thus notifying the RS of participation in a multicast transmission.

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Multicast routing protocols are used to determine which routers have directly attached hosts, as specified by IGMP, that have membership to a multicast session. Once host memberships are determined, routers use multicast routing protocols, such as DVMRP, to forward multicast traffic between routers.

The RS supports the following multicast routing protocols:

- Distance Vector Multicast Routing Protocol (DVMRP) RFC 1075
- Internet Group Management Protocol (IGMP) as described in RFC 2236

The RS also supports the latest DVMRP Version 3.0 draft specification, which includes mtrace, Generation ID and Pruning/Grafting. Configuring multicast routing for the RS is described in Chapter 19, *"Multicast Routing Configuration."*

11.2 CONFIGURING IP INTERFACES AND PARAMETERS

You can configure an IP interface to a single port or to a VLAN. This section provides an overview of configuring IP interfaces.

Interfaces on the RS are logical interfaces. Therefore, you can associate an interface with a single port or with multiple ports:

- To associate an interface with a single port, use the **`port`** option with the **`interface create`** command.
- To associate an interface with multiple ports, first create an IP VLAN and add ports to it, then use the vlan option with the **`interface create`** command.

The **`interface create ip`** command creates and configures an IP interface. Configuration of an IP interface can include information such as the interface's name, IP address, netmask, broadcast address, and so on. You can also create an interface in a disabled (**down**) state instead of the default enabled (**up**) state.

Note You must use either the **`port`** option or the **`vlan`** option with the **`interface create`** command.

11.2.1 Configuring IP Interfaces to Ports

You can configure an IP interface directly to a physical port. Each port can be assigned multiple IP addresses representing multiple subnets connected to the physical port. For example, to assign an IP interface 'RED' to physical port et.3.4, enter the following:

```
rs(config)# interface create ip RED address-netmask
10.50.0.0/255.255.0.0 port et.3.4
```

To configure a secondary address of 10.23.4.36 with a 24-bit netmask (255.255.255.0) on the IP interface int4:

```
rs(config)# interface add ip int4 address-netmask 10.23.4.36/24
```


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11.2.2 Configuring IP Interfaces for a VLAN

You can configure one IP interface per VLAN. Once an IP interface has been assigned to a VLAN, you can add a secondary IP address to the VLAN. To create a VLAN called IP3, add ports et.3.1 through et.3.4 to the VLAN, then create an IP interface on the VLAN:

```
rs(config)# vlan create IP3 ip

rs(config)# vlan add ports et.3.1-4 to IP3

rs(config)# interface create ip int3 address-netmask 10.20.3.42/24 vlan IP3
```

To configure a secondary address of 10.23.4.36 with a 24-bit netmask (255.255.255.0) on the IP interface int4:

```
rs(config)# interface add ip int3 address-netmask 10.23.4.36/24 vlan IP3
```

11.2.3 Specifying Ethernet Encapsulation Method

The Riverstone RS Switch Router supports two encapsulation types for IP. Use the **`interface create ip`** command to configure one of the following encapsulation types on a per-interface basis:

- Ethernet II: The standard ARPA Ethernet Version 2.0 encapsulation, which uses a 16-bit protocol type code (the default encapsulation method).
- 802.3 SNAP: SNAP IEEE 802.3 encapsulation, in which the type code becomes the frame length for the IEEE 802.2 LLC encapsulation (destination and source Service Access Points, and a control byte).

11.2.4 Unnumbered Interfaces

The Riverstone RS Switch Router allows you to create unnumbered IP interfaces. In the case where an interface is one end of a point-to-point connection, it is not necessary to associate a particular IP address to that interface. This is because in a point-to-point connection, packet traffic is going to the other end (or peer) only, and is not routed to any other destination. Therefore, assigning a unique IP address to that interface wastes addresses within the address pool allocated by the netmask.

Unnumbered interfaces allow you to use another interface's IP address. In essence, you configure the unnumbered interface to borrow the IP address from another interface. This way, the unnumbered interface does not use a unique IP address for itself, thus conserving addresses within the address pool.

To configure the unnumbered interface 'int3' and borrow the IP address from IP interface 'int1':

```
rs(config)# interface create ip int3 unnumbered int1 port so.3.1
```

If the interface 'int1' has multiple IP addresses, you can specify which address to borrow as shown in the following example:

```
rs(config)# interface create ip int3 unnumbered int1 unnumbered-addr
10.1.1.1 port so.3.1
```


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If you don't specify which address to borrow, then the first address of 'int1' is borrowed.

Note This feature cannot be used with multicast routing.

11.3 CONFIGURING JUMBO FRAMES

Certain RS line cards support jumbo frames (frames larger than the standard Ethernet frame size of 1518 bytes).

To transmit frames of up to 65535 octets, you increase the maximum transmission unit (MTU) size from the default of 1522. You must set the MTU at the port level with the **`port set mtu`** command. You can also set the MTU at the IP interface level; if you set the MTU at the IP interface level, the MTU size must be less than the size configured for each port in the interface. Note that the interface MTU only determines the size of the packets that are forwarded in software.

In the following example, the ports gi.3.1 through gi.3.8 are configured with an MTU size of 65535 octets. Ports gi.3.1 through gi.3.4 are configured to be part of the interface 'int3,' with an MTU size of 65000 octets.

```
rs(config)# port set gi.3.1-8 mtu 65535

rs(config)# vlan create JUMBO1 ip

rs(config)# vlan add ports gi.3.1-4 to JUMBO1

rs(config)# interface create ip int3 mtu 50000 address-netmask 10.20.3.42/24
vlan JUMBO1
```

If you do *not* set the MTU at the interface level, the actual MTU of the interface is the lowest MTU configured for a port in the interface. In the following example, port gi.3.1 is configured with an MTU size of 50022 octets while ports gi.3.2-8 are configured with an MTU size of 65535 octets. The interface MTU will be 50000 octets (50022 octets minus 22 octets of link layer overhead).

```
rs(config)# port set gi.3.1 mtu 50022

rs(config)# port set gi.3.2-8 mtu 65535

rs(config)# vlan create JUMBO1 ip

rs(config)# vlan add ports gi.3.1-4 to JUMBO1

rs(config)# interface create ip int3 address-netmask 10.20.3.42/24 vlan
JUMBO1
```


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11.4 CONFIGURING ADDRESS RESOLUTION PROTOCOL (ARP)

The RS allows you to configure Address Resolution Protocol (ARP) table entries and parameters. ARP is used to associate IP addresses with media or MAC addresses. Taking an IP address as input, ARP determines the associated MAC address. Once a media or MAC address is determined, the IP address/media address association is stored in an ARP cache for rapid retrieval. Then the IP datagram is encapsulated in a link-layer frame and sent over the network.

11.4.1 Configuring ARP Cache Entries

To create an ARP entry for the IP address 10.8.1.2 at port et.4.7 for 15 seconds:

```
rs# arp add 10.8.1.2 mac-addr 08:00:20:a2:f3:49 exit-port et.4.7
keep-time 15
```

To create a permanent ARP entry for the host *nfs2* at port et.3.1:

```
rs(config)# arp add nfs2 mac-addr 080020:13a09f exit-port et.3.1
```

To remove the ARP entry for the host 10.8.1.2 from the ARP table:.

```
rs# arp clear 10.8.1.2
```

To clear the entire ARP table.

```
rs# arp clear all
```

If the Startup configuration file contains **`arp add`** commands, the Control Module re-adds the ARP entries even if you have cleared them using the **`arp clear`** command. To permanently remove an ARP entry, use the **`negate`** command or **`no`** command to remove the entry.

11.4.2 Unresolved MAC Addresses for ARP Entries

When the RS receives a packet for a host whose MAC address it has not resolved, the RS tries to resolve the next-hop MAC address by sending ARP requests. Five requests are sent initially for each host, one every second.

You can configure the RS to drop packets for hosts whose MAC addresses the RS has been unable to resolve. To enable dropping of packets for hosts with unresolved MAC addresses:

```
rs# arp set drop-unresolved enabled
```

When you enable packets to be dropped for hosts with unresolved MAC addresses, the RS will still attempt to periodically resolve these MAC addresses. By default, the RS sends ARP requests at 5-second intervals to try to resolve dropped entries.

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To change the interval for sending ARP requests for unresolved entries to 45 seconds:

```
rs# arp set unresolve-timer 45
```

To change the number of unresolved entries that the RS attempts to resolve to 75:

```
rs# arp set unresolve-threshold 75
```

11.4.3 Configuring Proxy ARP

The RS can be configured for proxy ARP. The RS uses proxy ARP (as defined in RFC 1027) to help hosts with no knowledge of routing determine the MAC address of hosts on other networks or subnets. Through proxy ARP, the RS will respond to ARP requests from a host with a ARP reply packet containing the RS MAC address. Proxy ARP is enabled by default on the RS. The following example disables proxy ARP on all interfaces:

```
rs(config)# ip disable-proxy-arp interface all
```

11.5 CONFIGURING REVERSE ADDRESS RESOLUTION PROTOCOL (RARP)

Reverse Address Resolution Protocol (RARP) works exactly the opposite of ARP. Taking a MAC address as input, RARP determines the associated IP address. RARP is useful for X-terminals and diskless workstations that may not have an IP address when they boot. They can submit their MAC address to a RARP server on the RS, which returns an IP address.

Configuring RARP on the RS consists of two steps:

1. Letting the RS know which IP interfaces to respond to
2. Defining the mappings of MAC addresses to IP addresses

11.5.1 Specifying IP Interfaces for RARP

The **rarpd set interface** command allows you to specify which interfaces the RS's RARP server responds to when sent RARP requests. You can specify individual interfaces or all interfaces. To cause the RS's RARP server to respond to RARP requests from interface int1:

```
rs(config)# rarpd set interface int1
```


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11.5.2 Defining MAC-to-IP Address Mappings

The **rarpd add** command allows you to map a MAC address to an IP address for use with RARP. When a host makes a RARP request on the RS, and its MAC address has been mapped to an IP address with the **rarp add** command, the RARP server on the RS responds with the IP address that corresponds to the host's MAC address. To map MAC address 00:C0:4F:65:18:E0 to IP address 10.10.10.10:

```
rs(config)# rarpd add hardware-address 00:C0:4F:65:18:E0 ip-address
10.10.10.10
```

There is no limit to the number of address mappings you can configure.

Optionally, you can create a list of mappings with a text editor and then use TFTP to upload the text file to the RS. The format of the text file must be as follows:

```
MAC-address1 IP-address1
MAC-address2 IP-address2
...
MAC-addressn IP-addressn
```

Then place the text file on a TFTP server that the RS can access and enter the following command in Enable mode:

```
rs# copy tftp-server to ethers
TFTP server? <IPaddr-of-TFTP-server>
Source filename? <filename>
```

11.5.3 Monitoring RARP

You can use the following commands to obtain information about the RS's RARP configuration:

Display the interfaces to which the RARP server responds.	**rarpd show interface**
Display the existing MAC-to-IP address mappings	**rarpd show mappings**
Display RARP statistics.	**statistics show rarp** <*InterfaceName*>**|all**

11.6 CONFIGURING DNS PARAMETERS

The RS can be configured to specify DNS servers, which supply name services for DNS requests. You can specify up to three DNS servers.

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To configure three DNS servers and configure the RS's DNS domain name to "mrb.com":

```
rs(config)# system set dns server "10.1.2.3 10.2.10.12 10.3.4.5" domain
mrb.com
```

11.7 CONFIGURING IP SERVICES (ICMP)

The RS provides ICMP message capabilities including ping and traceroute. The **ping** command allows you to determine the reachability of a certain IP host, while the **traceroute** command allows you to trace the IP gateways to an IP host.

11.8 CONFIGURING IP HELPER

The **ip helper-address** command allows the user to forward specific UDP broadcast from one interface to another. Typically, broadcast packets from one interface are not forwarded (routed) to another interface. However, some applications use UDP broadcast to detect the availability of a service. Other services, for example BOOTP/DHCP require broadcast packets to be routed so that they can provide services to clients on another subnet. An IP helper can be configured on each interface to have UDP broadcast packets forwarded to a specific host for a specific service or forwarded to all other interfaces.

You can configure the RS to forward UDP broadcast packets received on a given interface to all other interfaces or to a specified IP address. You can specify a UDP port number for which UDP broadcast packets with that destination port number will be forwarded. By default, if no UDP port number is specified, the RS will forward UDP broadcast packets for the following six services:

- BOOTP/DHCP (port 67 and 68)
- DNS (port 37)
- NetBIOS Name Server (port 137)
- NetBIOS Datagram Server (port 138)
- TACACS Server (port 49)
- Time Service (port 37)

To forward UDP broadcast packets received on interface int1 to the host 10.1.4.5 for the six default UDP services:

```
rs(config)# ip helper-address interface int1 10.1.4.5
```

To forward UDP broadcast packets received on interface int2 to the host 10.2.48.8 for packets with the destination port 111 (port mapper):

```
rs(config)# ip helper-address interface int2 10.2.48.8 111
```

To forward UDP broadcast packets received on interface int3 to all other interfaces:

```
rs(config)# ip helper-address interface int3 all-interfaces
```


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11.9 CONFIGURING DIRECT BROADCAST

Directed broadcast packets are network or subnet broadcast packets which are sent to a router to be forwarded as broadcast packets. They can be misused to create Denial Of Service attacks. The RS protects against this possibility by ***not*** forwarding directed broadcasts, by default. To enable the forwarding of directed broadcasts, use the **`ip enable directed-broadcast`** command.

You can configure the RS to forward all directed broadcast traffic from the local subnet to a specified IP address or all associated IP addresses. This is a more efficient method than defining only one local interface and remote IP address destination at a time with the **`ip-helper`** command when you are forwarding traffic from more than one interface in the local subnet to a remote destination IP address.

To enable directed broadcast forwarding on the "int4" network interface:

```
rs(config)# ip enable directed-broadcast interface int4
```

11.10 CONFIGURING DENIAL OF SERVICE (DOS)

By default, the RS installs flows in the hardware so that packets sent as directed broadcasts are dropped in hardware, if directed broadcast is not enabled on the interface where the packet is received. You can disable this feature, causing directed broadcast packets to be processed on the RS even if directed broadcast is not enabled on the interface receiving the packet.

Similarly, the RS installs flows to drop packets destined for the RS for which service is not provided by the RS. This prevents packets for unknown services from slowing the CPU. You can disable this behavior, causing these packets to be processed by the CPU.

To cause directed broadcast packets to be processed on the RS, even if directed broadcast is not enabled on the interface receiving the packet:

```
rs(config)# ip dos disable directed-broadcast-protection
```

To allow packets destined for the RS, but do not have a service defined for them on the RS, to be processed by the RS's CPU:

```
rs(config)# ip dos disable port-attack-protection
```

11.11 MONITORING IP PARAMETERS

The RS provides display of IP statistics and configurations contained in the routing table. Information displayed provides routing and performance information.

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The **ip show** commands display IP information, such as routing tables, TCP/UDP connections, and IP interface configuration, on the RS. The following example displays all established connections and services of the RS.

```
rs# ip show connections
Active Internet connections (including servers)
Proto Recv-Q Send-Q  Local Address          Foreign Address
(state)
tcp        0      0  *:gated-gii           *:*                    LISTEN
tcp        0      0  *:http                *:*                    LISTEN
tcp        0      0  *:telnet              *:*                    LISTEN
udp        0      0  127.0.0.1:1025        127.0.0.1:162
udp        0      0  *:snmp                *:*
udp        0      0  *:snmp-trap           *:*
udp        0      0  *:bootp-relay         *:*
udp        0      0  *:route               *:*
udp        0      0  *:*                   *:*
```

The following example displays the contents of the routing table. It shows that some of the route entries are for locally connected interfaces ("directly connected"), while some of the other routes are learned from RIP.

```
rs# ip show routes
Destination                Gateway                   Owner     Netif
-----------                -------                   -----     -----
10.1.0.0/16               50.1.1.2                  RIP       to-linux2
10.2.0.0/16               50.1.1.2                  RIP       to-linux2
10.3.0.0/16               50.1.1.2                  RIP       to-linux2
10.4.0.0/16               50.1.1.2                  RIP       to-linux2
14.3.2.1                   61.1.4.32                   Static    int61
21.0.0.0/8                50.1.1.2                  RIP       to-linux2
30.1.0.0/16                directly connected          -         to-goya
50.1.0.0/16                directly connected          -
to-linux2
61.1.0.0/16                directly connected          -         int61
62.1.0.0/16               50.1.1.2                  RIP       to-linux2
68.1.0.0/16                directly connected          -         int68
69.1.0.0/16               50.1.1.2                  RIP       to-linux2
127.0.0.0/8                127.0.0.1                   Static    lo
127.0.0.1                  127.0.0.1                   -         lo
210.11.99.0/24             directly connected          -         int41
```

To display additional IP information, enter the following command in Enable mode:

Show ARP table entries.	**arp show all**
Show IP interface configuration.	**interface show ip**
Show DNS parameters.	**system show dns**

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11.12 CONFIGURING IP FORWARDING

When the RS receives a packet for routing, it uses either the Hardware Routing Table (HRT) or one of the following forwarding modes to forward the packet:

- application-based forwarding (default)
- destination-based forwarding
- host-flow-based forwarding
- custom forwarding profile

11.13 HARDWARE ROUTING TABLE

You can enable forwarding using the Hardware Routing Table (HRT) on the RS. When the RS receives a packet for routing, it retrieves the packet's destination IP address (DIP) and uses a series of three lookup tables to locate the next hop address. If the RS does not find the packet's destination IP address through the HRT, it drops the packet. The advantage of this type of routing is that packets almost never get sent to the CPU, using up CPU process time, except in a few cases such as multicasting.

You can enable the use of the HRT on the RS, by entering the following command in Configure mode. After entering the command, save it to the active configuration file and reboot the system.

```
hrt enable slot <slot number>|all
```

If HRT is not enabled, the RS routes packets by using the L3 flow tables.

11.14 CONFIGURING ICMP REDIRECT

The RS sends ICMP redirect messages when it receives packets that have the same entry and exit ports. When HRT is enabled, you can set a threshold for these types of packets. Once the number of packets received by the RS reaches the specified threshold, the RS will send an ICMP redirect message to the originating device. To do so, enter the following command in Configure mode:.

```
hrt set icmp icmp-redirect-count <number>
```

Note HRT is not supported on the following modules: ATM-OC3, ATM-OC12, HSSI, Serial and CMTS.

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11.15 FORWARDING MODE

When the RS receives a packet for routing, it extracts flow information which is used to determine the packets exit port and QoS requirements. By default, the RS uses application-based forwarding wherein it extracts the complete application (layer-4) flow from an IP packet. The RS then matches the packet's flow information against flows found in the flow table. If a match is found, the packet is forwarded to the output port and transmitted. If a match is not found, the packet is forwarded to the CPU for additional processing.

To reduce the amount of processing done by the CPU and to use the flow table more efficiently, you can configure the RS to extract only certain fields from the packet's L3 header. The RS supports three types of forwarding modes:

- destination-based
- host-flow based
- custom forwarding profile

11.15.1 Configuring Destination-Based and Host-Flow-Based Forwarding

Use the **`ip set port forwarding-mode`** command to configure the ports on the RS to use either the destination-based or host-flow-based forwarding mode. These modes determine which fields are extracted from a packet's L3 header and used to determine the port list and QoS requirements.

When the RS uses destination-based forwarding, it extracts the destination IP address, TOS, and L4 protocol fields from IP unicast packets. For multicast packets, the RS extracts the destination IP address, source IP address, TOS, and L4 protocol fields.

When the RS uses host-flow-based forwarding, it extracts the destination IP address, source IP address, TOS, and L4 protocol fields from the IP packet.

To configure a port's forwarding mode, enter the following command in Configure mode:.

```
ip set port <port-list> forwarding mode
<destination-based|host-flow-based>
```

11.15.2 Configuring a Custom Forwarding Profile

You can configure the RS to use a custom forwarding profile to determine which fields are extracted to identify the packet's flow. A custom forwarding profile is used to wildcard specific fields in the IP header.

You can apply a custom forwarding profile to an RS's slot, then enable it on a per port basis. When you do so, those ports on which custom forwarding profile is not enabled will use the default forwarding mode.

The fields that can be wild carded are as follows:

- Source IP Address (SIP)
- Destination IP Address (DIP)
- Protocol
- Source Socket
- Destination Socket
- Type of Service (TOS)

To configure a custom forwarding profile, perform the following tasks:

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- define a profile
- apply the profile to a slot
- enable the profile on a specific port

Defining a Profile

When you define a custom forwarding profile, you should identify it and specify which fields will be wild carded:

Use the following command to define a custom forwarding profile.

```
ip define custom-forwarding-profile <string> sip-host-wildcard |
dip-host-wildcard | proto-wilcard |dst-sock-wildcard |src-sock-wildcard
| tos-wildcard
```

Applying a Profile

You can apply a profile to a slot. AFter you apply it to a slot, you should enable it on the ports in a slot.

Use the following command to apply a profile to a slot.

```
ip apply custom-forwarding-mode <string>
```

Enabling a Port

After you apply a custom forwarding profile to a slot, you can enable it on a per port basis. Ports on which the forwarding profile is enabled will use it to forward packets. Ports on which the forwarding profile is not enabled will use the default forwarding mode.

To enable custom forwarding on a port:

```
ip enable custom-forwarding-mode port <port-list>
```

11.15.3 Monitoring Custom Forwarding Profiles

To view custom forwarding profiles, enter any of the following commands in Enable mode:.

Display one or more custom forwarding profiles.	**ip show custom-forwarding-profile** *<string>* **| all**
Display the custom forwarding profile of the specified slot(s).	**ip show custom-forwarding-mode slot** *<number>* **|all**

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11.15.4 Using Custom Forwarding with Other RS Features

Custom forwarding profiles are used to wildcard certain fields in the IP header. This can cause incompatibility with various RS features that require that these fields not be wild carded. Therefore, whenever custom forwarding is enabled on a port, the RS checks for compatibility with other features that the port supports. Conversely, when a feature is applied to an interface or VLAN with ports in custom forwarding mode, the RS also checks for compatibility.

Access Control Lists (ACLs)

An ACL specifies various fields on the IP header which it uses to filter out packets. Thus, when an ACL is applied to an interface, the RS checks to see if any of the ports on the interface have custom forwarding enabled. For any port in which custom forwarding is enabled, the RS makes an additional check that the fields specified in the ACL are not wild carded by the custom forwarding profile. If this happens, the RS generates an error. Conversely, when a port in custom forwarding mode is added to an interface, VLAN or SmartTrunk, the RS checks for compatibility between the custom profile and the existing ACLs.

Network Address Translation (NAT)

NAT requires the source IP address and sometimes the source socket for address translation. Thus, the RS checks if the source IP and source socket are wild carded whenever NAT is enabled on an interface or a custom forwarding profile is applied to a NAT enabled interface.

Rate Limiting

Rate limiting uses ACLs to limit traffic rate. Thus, the RS performs a compatibility check when a port is requires to support both custom forwarding and rate limiting.

Quality of Service (QoS)

QoS policies applied at L3, require certain fields in the IP header, such as source IP and destination IP. The RS performs a compatibility check when a QoS policy is applied to a port in forwarding mode .

L4 Bridging

L4 bridging is incompatible with custom forwarding profiles. Therefore a port cannot support l4 bridging and custom forwarding at the same time.

11.16 CONFIGURING ROUTER DISCOVERY

The router discovery server on the RS periodically sends out router advertisements to announce the existence of the RS to other hosts. The router advertisements are multicast or broadcast to each interface on the RS on which it is enabled and contain a list of the addresses on the interface and the preference of each address for use as a default route for the interface. A host can also send a router solicitation, to which the router discovery server on the RS will respond with a unicast router advertisement.

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On systems that support IP multicasting, router advertisements are sent to the 'all-hosts' multicast address 224.0.0.1 by default. You can specify that broadcast be used, even if IP multicasting is available. When router advertisements are sent to the all-hosts multicast address or an interface is configured for the limited broadcast address 255.255.255.255, the router advertisement includes all IP addresses configured on the physical interface. When router advertisements are sent to a net or subnet broadcast, then only the address associated with the net or subnet is included.

To start router discovery on the RS, enter the following command in Configure mode:

```
rs(config)# rdisc start
```

The **rdisc start** command lets you start router discovery on the RS. When router discovery is started, the RS multicasts or broadcasts periodic router advertisements on each configured interface. The router advertisements contain a list of addresses on a given interface and the preference of each address for use as the default route on the interface. By default, router discovery is disabled.

The **rdisc add address** command lets you define addresses to be included in router advertisements. If you configure this command, only the specified hostname(s) or IP address(es) are included in the router advertisements. For example::

```
rs(config)# rdisc add address 10.10.5.254
```

By default, all addresses on the interface are included in router advertisements sent by the RS. The **rdisc add interface** command lets you enable router advertisement on an interface. For example::

```
rs(config)# rdisc add interface rs4
```

If you want to have only specific addresses included in router advertisements, use the **rdisc add address** command to specify those addresses.

The **rdisc set address** command lets you specify the type of router advertisement in which the address is included and the preference of the address for use as a default route. For example, to specify that an address be included only in broadcast router advertisements and that the address is ineligible to be a default route:

```
rs#(config) rdisc set address 10.20.36.0 type broadcast preference
ineligible
```

The **rdisc set interface** command lets you specify the intervals between the sending of router advertisements and the lifetime of addresses sent in a router advertisement. To specify the maximum time between the sending of router advertisements on an interface:

```
rs#(config) rdisc set interface rs4 max-adv-interval 1200
```


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To display router discovery information:

```
rs# rdisc show all


Task State: <Foreground NoResolv NoDetach> ❶

    Send buffer size 2048 at 812C68F8
    Recv buffer size 2048 at 812C60D0

Timers:

    RouterDiscoveryServer Priority 30

        RouterDiscoveryServer_RS2_RS3_IP <OneShot>
            last: 10:17:21 next: 10:25:05  ❷

Task RouterDiscoveryServer:
    Interfaces:
        Interface RS2_RS3_IP: ❸
            Group 224.0.0.1: ❹
                minadvint 7:30 maxadvint 10:00 lifetime 30:00 ❺

                Address 10.10.5.254: Preference: 0 ❻

    Interface policy:
        Interface RS2_RS3_IP* MaxAdvInt 10:00 ❼
```

Legend:

1. Information about the RDISC task.
2. Shows when the last router advertisement was sent and when the next advertisement will be sent.
3. The interface on which router advertisement is enabled.
4. Multicast address.
5. Current values for the intervals between the sending of router advertisements and the lifetime of addresses sent in a router advertisement.
6. IP address that is included in router advertisement. The preference of this address as a default route is 0, the default value.
7. Shows configured values for the specified interface.

11.17 SETTING MEMORY THRESHOLDS

The routing information base (RIB) is stored in memory in the RS. There are four configurable thresholds that represent the percentages of the available memory that is used for storing RIB entries.

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The default memory thresholds are shown in Table 11-1. You can use the **`ip-router global set memory-threshold`** command to change the thresholds.

Table 11-1 Default Memory Thresholds

Threshold Level	Percentage of Memory
level-1	**60**
level-2	**65**
level-3	**70**
level-4	**75**

When a level-1, level-2, or level-3 threshold is reached, the RS may delete routes in the RIB or not add new routes to the RIB, depending upon the routing protocol. When threshold level-4 is reached (by default, 75% of available memory used by the RIB), no new routes are added.

Table 11-2 shows what actions the RS takes in updating the RIB when each threshold is reached.

Table 11-2 RIB Updates When Memory Threshold is Reached

Route Protocol	Threshold	Action
OSPF/ IS-IS	level-1 level-2 level-3 level-4	Updates are processed as usual.
RIP	level-1	• A new RIP route is added only if it is the *only* RIP route to the given destination. • Maximum of 2 routes allowed to a given destination. If there are more than 2 routes to a given destination, the least preferred route(s) are deleted.
	level-2	• A new RIP route is added only if is an active RIP route to the given destination.
	level-3	• Only one route is allowed to a given destination. If there is more than one route to a given destination, the least preferred route is deleted.
	level-4	No new routes are added.

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Table 11-2 RIB Updates When Memory Threshold is Reached

Route Protocol	Threshold	Action
BGP	level-1 level-2	• A new BGP route is added only if it is the *only* BGP route to the given destination. • Maximum of 3 routes allowed to a given destination. If there are more than 3 routes to a given destination, a new route replaces an existing route.
	level-3	• Maximum of 2 routes allowed to a given destination. If there are more than 2 routes to a given destination, a new route replaces an existing route.
	level-4	No new routes are added.

The **`ip-router show summary drops`** command shows information about routes that were deleted or not added due to low memory, as well as the current threshold settings.

11.18 CONFIGURATION EXAMPLES

11.18.1 Assigning IP/IPX Interfaces

To enable routing on the RS, you must assign an IP or IPX interface to a VLAN. To assign an IP or IPX interface named 'RED' to the 'BLUE' VLAN, enter the following command:

```
rs(config)# interface create ip RED address-netmask
10.50.0.1/255.255.0.0 vlan BLUE
```

You can also assign an IP or IPX interface directly to a physical port.

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12 VRRP CONFIGURATION GUIDE

This chapter explains how to set up and monitor the Virtual Router Redundancy Protocol (VRRP) on the RS. VRRP is defined in RFC 2338.

End host systems on a LAN are often configured to send packets to a statically configured default router. If this default router becomes unavailable, all the hosts that use it as their first hop router become isolated on the network. VRRP provides a way to ensure the availability of an end host's default router.

This is done by assigning IP addresses that end hosts use as their default route to a "virtual router." A Master router is assigned to forward traffic designated for the virtual router. If the Master router should become unavailable, a backup router takes over and begins forwarding traffic for the virtual router. As long as one of the routers in a VRRP configuration is up, the IP addresses assigned to the virtual router are always available, and the end hosts can send packets to these IP addresses without interruption.

12.1 CONFIGURING VRRP

This section presents three sample VRRP configurations:

- A basic VRRP configuration with one virtual router
- A symmetrical VRRP configuration with two virtual routers
- A multi-backup VRRP configuration with three virtual routers

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12.1.1 Basic VRRP Configuration

Figure 12-1 shows a basic VRRP configuration with a single virtual router. Routers R1 and R2 are both configured with one virtual router (VRID=1). Router R1 serves as the Master and Router R2 serves as the Backup. The four end hosts are configured to use 10.0.0.1/16 as the default route. IP address 10.0.0.1/16 is associated with virtual router VRID=1.

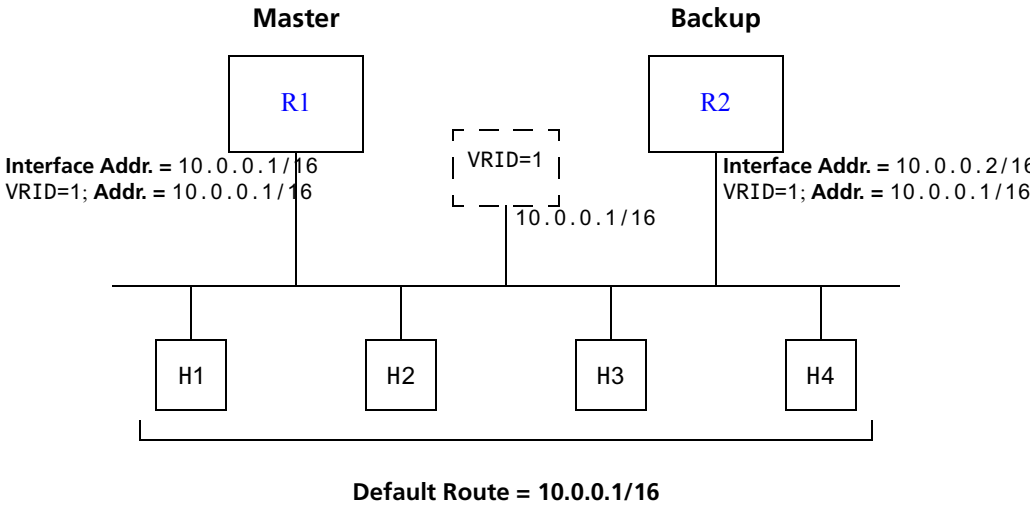

Figure 12-1 Basic VRRP configuration

If Router R1 should become unavailable, Router R2 would take over virtual router VRID=1 and its associated IP addresses. Packets sent to 10.0.0.1/16 would go to Router R2. When Router R1 comes up again, it would take over as Master, and Router R2 would revert to Backup.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 12-1.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
4: ip-redundancy start vrrp 1 interface test
```

Line 1 adds IP address 10.0.0.1/16 to interface test, making Router R1 the owner of this IP address. Line 2 creates virtual router VRID=1 on interface test. Line 3 associates IP address 10.0.0.1/16 with virtual router VRID=1. Line 4 starts VRRP on interface test.

In VRRP, the router that owns the IP address associated with the virtual router is the Master. Any other routers that participate in this virtual router are Backups. In this configuration, Router R1 is the Master for virtual router VRID=1 because it owns 10.0.0.1/16, the IP address associated with virtual router VRID=1.

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Configuration for Router R2

The following is the configuration file for Router R2 in Figure 12-1.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
4: ip-redundancy start vrrp 1 interface test
```

The configuration for Router R2 is nearly identical to Router R1. The difference is that Router R2 does not own IP address 10.0.0.1/16. Since Router R2 does not own this IP address, it is the Backup. It will take over from the Master if it should become unavailable.

12.1.2 Symmetrical Configuration

Figure 12-2 shows a VRRP configuration with two routers and two virtual routers. Routers R1 and R2 are both configured with two virtual routers (`VRID=1` and `VRID=2`).

Router R1 serves as:

- Master for `VRID=1`
- Backup for `VRID=2`

Router R2 serves as:

- Master for `VRID=2`
- Backup for `VRID=1`

This configuration allows you to load-balance traffic coming from the hosts on the 10.0.0.0/16 subnet and provides a redundant path to either virtual router.

Note This is the recommended configuration on a network using VRRP.

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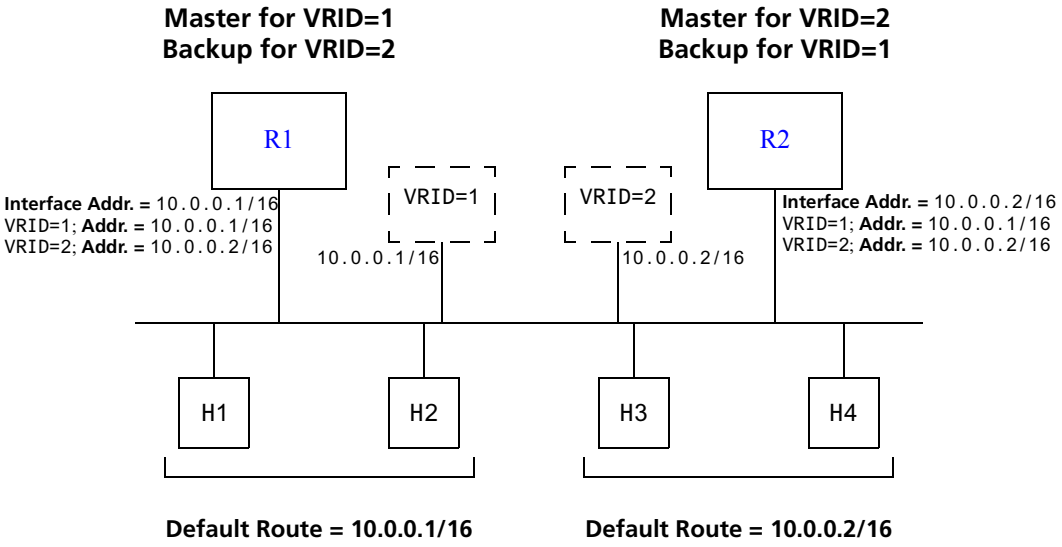

Figure 12-2 Symmetrical VRRP configuration

In this configuration, half the hosts use 10.0.0.1/16 as their default route, and half use 10.0.0.2/16. IP address 10.0.0.1/16 is associated with virtual router `VRID=1`, and IP address 10.0.0.2/16 is associated with virtual router `VRID=2`.

If Router R1, the Master for virtual router `VRID=1`, goes down, Router R2 would take over the IP address 10.0.0.1/16. Similarly, if Router R2, the Master for virtual router `VRID=2`, goes down, Router R1 would take over the IP address 10.0.0.2/16.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 12-2.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
     !
4: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
5: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
     !
6: ip-redundancy start vrrp 1 interface test
7: ip-redundancy start vrrp 2 interface test
```

Router R1 is the owner of IP address 10.0.0.1/16. Line 4 associates this IP address with virtual router `VRID=1`, so Router R1 is the Master for virtual router `VRID=1`.

On line 5, Router R1 associates IP address 10.0.0.2/16 with virtual router `VRID=2`. However, since Router R1 does not own IP address 10.0.0.2/16, it is not the default Master for virtual router `VRID=2`.

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Configuration of Router R2

The following is the configuration file for Router R2 in Figure 12-2.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
     !
4: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
5: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
     !
6: ip-redundancy start vrrp 1 interface test
7: ip-redundancy start vrrp 2 interface test
```

On line 1, Router R2 is made owner of IP address 10.0.0.2/16. Line 5 associates this IP address with virtual router `VRID=2`, so Router R2 is the Master for virtual router `VRID=2`. Line 4 associates IP address 10.0.0.1/16 with virtual router `VRID=1`, making Router R2 the Backup for virtual router `VRID=1`.

12.1.3 Multi-Backup Configuration

Figure 12-3 shows a VRRP configuration with three routers and three virtual routers. Each router serves as a Master for one virtual router and as a Backup for each of the others. When a Master router goes down, one of the Backups takes over the IP addresses of its virtual router.

In a VRRP configuration where more than one router is backing up a Master, you can specify which Backup router takes over when the Master goes down by setting the priority for the Backup routers.

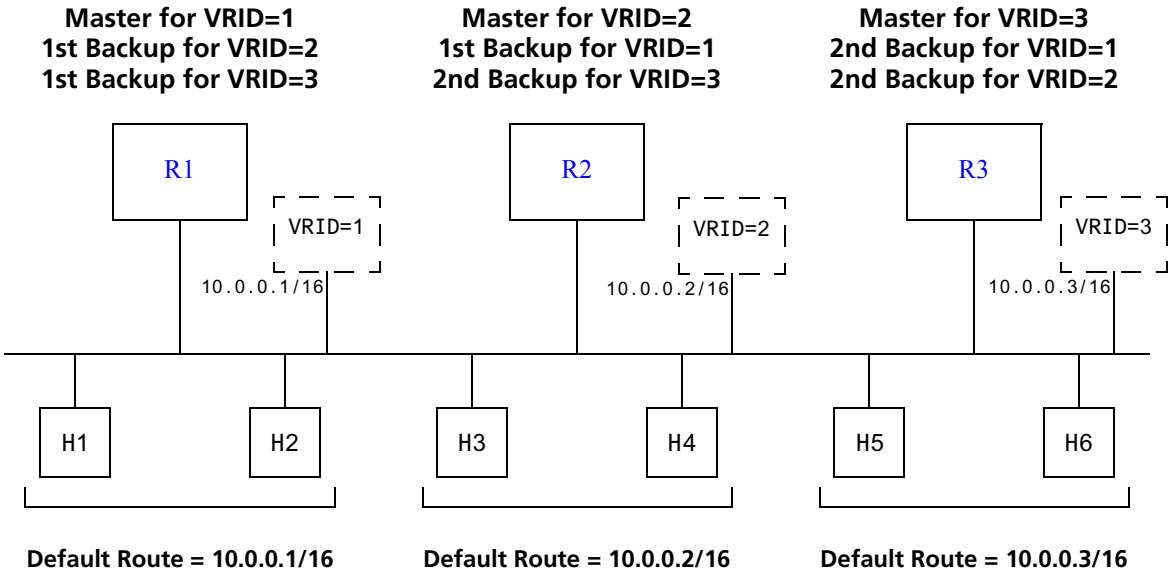

Figure 12-3 Multi-Backup VRRP configuration

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In this configuration, Router R1 is the Master for virtual router VRID=1 and the primary Backup for virtual routers VRID=2 and VRID=3. If Router R2 or R3 were to go down, Router R1 would assume the IP addresses associated with virtual routers VRID=2 and VRID=3.

Router R2 is the Master for virtual router VRID=2, the primary backup for virtual router VRID=1, and the secondary Backup for virtual router VRID=3. If Router R1 should fail, Router R2 would become the Master for virtual router VRID=1. If both Routers R1 and R3 should fail, Router R2 would become the Master for all three virtual routers. Packets sent to IP addresses 10.0.0.1/16, 10.0.0.2/16, and 10.0.0.3/16 would all go to Router R2.

Router R3 is the secondary Backup for virtual routers VRID=1 and VRID=2. It would become a Master router only if both Routers R1 and R2 should fail. In such a case, Router R3 would become the Master for all three virtual routers.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 12-3.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 2 interface test priority 200
9: ip-redundancy set vrrp 3 interface test priority 200
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Router R1's IP address on interface test is 10.0.0.1. There are three virtual routers on this interface:

- VRID=1 – IP address=10.0.0.1/16
- VRID=2 – IP address=10.0.0.2/16
- VRID=3 – IP address=10.0.0.3/16

Since the IP address of virtual router VRID=1 is the same as the interface's IP address (10.0.0.1), then the router automatically becomes the address owner of virtual router VRID=1.

A priority is associated with each of the virtual routers. The priority determines whether the router will become the Master or the Backup for a particular virtual router. Priorities can have values between 1 and 255. When a Master router goes down, the router with the next-highest priority takes over the virtual router. If more than one router has the next-highest priority, the router that has the highest-numbered interface IP address becomes the Master.

If a router is the address owner for a virtual router, then its priority for that virtual router is 255 and cannot be changed. If a router is ***not*** the address-owner for a virtual-router, then its priority for that virtual router is 100 by default, and can be changed by the user.

Since Router R1 is the owner of the IP address associated with virtual router VRID=1, it has a priority of 255 (the highest) for virtual router VRID=1. Lines 8 and 9 set Router R1's priority for virtual routers VRID=2 and VRID=3 at 200. If no other routers in the VRRP configuration have a higher priority, Router R1 will take over as Master for virtual routers VRID=2 and VRID=3, should Router R2 or R3 go down.

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The following table shows the priorities for each virtual router configured on Router R1.

Virtual Router	Default Priority	Configured Priority
VRID=1 – IP address=10.0.0.1/16	255 (address owner)	255 (address owner)
VRID=2 – IP address=10.0.0.2/16	100	200 (see line 8)
VRID=3 – IP address=10.0.0.3/16	100	200 (see line 9)

Configuration of Router R2

The following is the configuration file for Router R2 in Figure 12-3.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 1 interface test priority 200
9: ip-redundancy set vrrp 3 interface test priority 100
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Line 8 sets the backup priority for virtual router VRID=1 to 200. Since this number is higher than Router R3's backup priority for virtual router VRID=1, Router R2 is the primary Backup, and Router R3 is the secondary Backup for virtual router VRID=1.

On line 9, the backup priority for virtual router VRID=3 is set to 100. Since Router R1's backup priority for this virtual router is 200, Router R1 is the primary Backup, and Router R2 is the secondary Backup for virtual router VRID=3.

The following table shows the priorities for each virtual router configured on Router R2.

Virtual Router	Default Priority	Configured Priority
VRID=1 – IP address=10.0.0.1/16	100	200 (see line 8)
VRID=2 – IP address=10.0.0.2/16	255 (address owner)	255 (address owner)
VRID=3 – IP address=10.0.0.3/16	100	100 (see line 9)

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Note Since 100 is the default priority, line 9, which sets the priority to 100, is actually unnecessary. It is included for illustration purposes only.

Configuration of Router R3

The following is the configuration file for Router R3 in Figure 12-3.

```
1: interface create ip test address-netmask 10.0.0.3/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 1 interface test priority 100
9: ip-redundancy set vrrp 2 interface test priority 100
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Lines 8 and 9 set the backup priority for Router R3 at 100 for virtual routers `VRID=1` and `VRID=2`. Since Router R1 has a priority of 200 for backing up virtual router `VRID=2`, and Router R2 has a priority of 200 for backing up virtual router `VRID=1`, Router R3 is the secondary Backup for both virtual routers `VRID=1` and `VRID=2`.

The following table shows the priorities for each virtual router configured on Router R3.

Virtual Router	Default Priority	Configured Priority
`VRID=1` – IP address=10.0.0.1/16	100	100 (see line 8)
`VRID=2` – IP address=10.0.0.2/16	100	100 (see line 9)
`VRID=3` – IP address=10.0.0.3/16	255 (address owner)	255 (address owner)

Note Since 100 is the default priority, lines 8 and 9, which set the priority to 100, are actually unnecessary. They are included for illustration purposes only.

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12.2 ADDITIONAL CONFIGURATION

This section covers settings you can modify in a VRRP configuration, including backup priority, advertisement interval, pre-empt mode, and authentication key.

12.2.1 Setting the Backup Priority

As described in Section 12.1.3, *"Multi-Backup Configuration"*, you can specify which Backup router takes over when the Master router goes down by setting the priority for the Backup routers. To set the priority for a Backup router, enter the following command in Configure mode:

To specify 200 as the priority used by virtual router 1 on interface int1:

```
rs(config)# ip-redundancy set vrrp 1 interface int1 priority 200
```

The priority can be between 1 (lowest) and 254. The default is 100. The priority for the IP address owner is 255 and cannot be changed.

12.2.2 Setting the Warmup Period

When the Master router goes down, the Backup router takes over. When an interface comes up, the Master router may become available and take over from the Backup router. Before the Master router takes over, it may have to update its routing tables. You can specify a warmup period, in seconds, during which the Master router can update its routing information before it preempts the existing Master router.

To specify a warmup period for a Master router before it takes over:

```
rs(config)# ip-redundancy set vrrp 1 warmup-period 20
```

The warmup period can be between 1 and 180 seconds. The default is 30 seconds.

12.2.3 Setting the Advertisement Interval

The VRRP Master router sends periodic advertisement messages to let the other routers know that the Master is up and running. By default, advertisement messages are sent once each second. To change the VRRP advertisement interval, enter the following command in Configure mode:

To set the advertisement interval to 3 seconds:

```
rs(config)# ip-redundancy set vrrp 1 interface int1 adv-interval 3
```


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12.2.4 Setting Pre-empt Mode

When a Master router goes down, the Backup with the highest priority takes over the IP addresses associated with the Master. By default, when the original Master comes back up again, it takes over from the Backup router that assumed its role as Master. When a VRRP router does this, it is said to be in *pre-empt mode*. Pre-empt mode is enabled by default on the RS. You can prevent a VRRP router from taking over from a lower-priority Master by disabling pre-empt mode. To do this, enter the following command in Configure mode:

To prevent a Backup router from taking over as Master from a Master router that has a lower priority*:*

```
rs(config)# ip-redundancy set vrrp 1 interface int1 preempt-mode
disabled
```

Note If the IP address owner is available, then it will always take over as the Master, regardless of whether pre-empt mode is on or off.

12.2.5 Setting an Authentication Key

By default, no authentication of VRRP packets is performed on the RS. You can specify a clear-text password to be used to authenticate VRRP exchanges. To enable authentication, enter the following command in Configure mode

To authenticate VRRP exchanges on virtual router 1 on interface int1 with a password of ‘yago’*:*

```
rs(config)# ip-redundancy set vrrp 1 interface int1 auth-type text
auth-key yago
```

Note The RS does not currently support the IP Authentication Header method of authentication.

12.3 MONITORING VRRP

The RS provides two commands for monitoring a VRRP configuration: **`ip-redundancy trace`**, which displays messages when VRRP events occur, and **`ip-redundancy show`**, which reports statistics about virtual routers.

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12.3.1 ip-redundancy trace

The **ip-redundancy trace** command is used for troubleshooting purposes. This command causes messages to be displayed when certain VRRP events occur on the RS. To trace VRRP events, enter the following commands in Enable mode:

Display a message when any VRRP event occurs. (Disabled by default.)	**ip-redundancy trace vrrp events enabled**
Display a message when a VRRP router changes from one state to another; for example Backup to Master. (Enabled by default.)	**ip-redundancy trace vrrp state-transitions enabled**
Display a message when a VRRP packet error is detected. (Enabled by default.)	**ip-redundancy trace vrrp packet-errors enabled**
Enable all VRRP tracing.	**ip-redundancy trace vrrp all enabled**

12.3.2 ip-redundancy show

The **ip-redundancy show** command reports information about a VRRP configuration.

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To display information about all virtual routers on interface int1:

```
rs# ip-redundancy show vrrp interface int1

VRRP Virtual Router 100 - Interface int1
----------------------------------------
Uptime                  0 days, 0 hours, 0 minutes, 17 seconds.
State                   Backup
Priority                100 (default value)
Virtual MAC address     00005E:000164
Advertise Interval      1 sec(s) (default value)
Preempt Mode            Enabled (default value)
Authentication          None (default value)
Primary Address         10.8.0.2
Associated Addresses    10.8.0.1
                        100.0.0.1

VRRP Virtual Router 200 - Interface int1
----------------------------------------
Uptime                  0 days, 0 hours, 0 minutes, 17 seconds.
State                   Master
Priority                255 (default value)
Virtual MAC address     00005E:0001C8
Advertise Interval      1 sec(s) (default value)
Preempt Mode            Enabled (default value)
Authentication          None (default value)
Primary Address         10.8.0.2
Associated Addresses    10.8.0.2
```


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To display VRRP statistics for virtual router 100 on interface int1*:*

```
rs# ip-redundancy show vrrp 1 interface int1 verbose

VRRP Virtual Router 100 - Interface int1
----------------------------------------
Uptime                  0 days, 0 hours, 0 minutes, 17 seconds.
State                   Backup
Priority                100 (default value)
Virtual MAC address     00005E:000164
Advertise Interval      1 sec(s) (default value)
Preempt Mode            Enabled (default value)
Authentication          None (default value)
Primary Address         10.8.0.2
Associated Addresses    10.8.0.1
                        100.0.0.1

Stats:
  Number of transitions to master state           2
  VRRP advertisements rcvd                        0
  VRRP packets sent with 0 priority               1
  VRRP packets rcvd with 0 priority               0
  VRRP packets rcvd with IP-address list mismatch 0
  VRRP packets rcvd with auth-type mismatch       0
  VRRP packets rcvd with checksum error           0
  VRRP packets rcvd with invalid version          0
  VRRP packets rcvd with invalid VR-Id            0
  VRRP packets rcvd with invalid adv-interval     0
  VRRP packets rcvd with invalid TTL              0
  VRRP packets rcvd with invalid 'type' field     0
  VRRP packets rcvd with invalid auth-type        0
  VRRP packets rcvd with invalid auth-key         0
```

To display VRRP information, enter the following commands in Enable mode.

Display information about all virtual routers.	**ip-redundancy show vrrp**

12.4 VRRP CONFIGURATION NOTES

- The Master router sends keep-alive advertisements. The frequency of these keep-alive advertisements is determined by setting the Advertisement interval parameter. The default value is 1 second.
- If a Backup router doesn't receive a keep-alive advertisement from the current Master within a certain period of time, it will transition to the Master state and start sending advertisements itself. The amount of time that a Backup router will wait before it becomes the new Master is based on the following equation:

  Master-down-interval = (3 * advertisement-interval) + skew-time

  The skew-time depends on the Backup router's configured priority:

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Skew-time = ((256 - Priority) / 256)

Therefore, the higher the priority, the faster a Backup router will detect that the Master is down. For example:

- Default advertisement-interval = 1 second
- Default Backup router priority = 100
- Master-down-interval = time it takes a Backup to detect the Master is down

  = (3 * adv-interval) + skew-time

  = (3 * 1 second) + ((256 - 100) / 256)

  = 3.6 seconds

- If a Master router is manually rebooted, or if its interface is manually brought down, it will send a special keep-alive advertisement that lets the Backup routers know that a new Master is needed immediately.
- A virtual router will respond to ARP requests with a virtual MAC address. This virtual MAC depends on the virtual router ID:

  virtual MAC address = 00005E:0001*XX*

  where *XX* is the virtual router ID

  This virtual MAC address is also used as the source MAC address of the keep-alive Advertisements transmitted by the Master router.
- If multiple virtual routers are created on a single interface, the virtual routers must have unique identifiers. If virtual routers are created on different interfaces, you can reuse virtual router IDs .

  For example, the following configuration is valid:

```
ip-redundancy create vrrp 1 interface test-A
ip-redundancy create vrrp 1 interface test-B
```

- As specified in RFC 2338, a Backup router that has transitioned to Master will not respond to pings, accept telnet sessions, or field SNMP requests directed at the virtual router's IP address.

  Not responding allows network management to notice that the original Master router (i.e., the IP address owner) is down.

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13 RIP CONFIGURATION GUIDE

This chapter describes how to configure the Routing Information Protocol (RIP) on the Riverstone RS Switch Router. RIP is a distance-vector routing protocol for use in small networks. RIP is described in RFC 1723. A router running RIP broadcasts updates at set intervals. Each update contains paired values where each pair consists of an IP network address and an integer distance to that network. RIP uses a hop count metric to measure the distance to a destination.

The Riverstone RS Switch Router provides support for RIP Version 1 and 2. The RS implements plain text and MD5 authentication methods for RIP Version 2.

The protocol independent features that apply to RIP are described in Chapter 11, *"IP Routing Configuration Guide."*

13.1 CONFIGURING RIP

By default, RIP is disabled on the RS and on each of the attached interfaces. To configure RIP on the RS, follow these steps:

1. Start the RIP process by entering the **`rip start`** command.
2. Use the **`rip add interface`** command to inform RIP about the attached interfaces.

13.1.1 Enabling and Disabling RIP

To enable or disable RIP, enter one of the following commands in Configure mode.

Enable RIP.	**`rip start`**
Disable RIP.	**`rip stop`**

13.1.2 Configuring RIP Interfaces

To configure RIP in the RS, you must first add interfaces to inform RIP about attached interfaces.

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To add RIP interfaces, enter the following commands in Configure mode.

Add interfaces to the RIP process.	**rip add interface** <*interfacename-or-IPaddr*>
Add gateways from which the RS will accept RIP updates.	**rip add trusted-gateway** <*interfacename-or-IPaddr*>
Define the list of routers to which RIP sends packets directly, not through multicast or broadcast.	**rip add source-gateway** <*interfacename-or-IPaddr*>

13.2 CONFIGURING RIP PARAMETERS

No further configuration is required, and the system default parameters will be used by RIP to exchange routing information. These default parameters may be modified to suit your needs by using the **rip set interface** command.

RIP Parameter	Default Value
Version number	RIP v1
Check-zero for RIP reserved parameters	Enabled
Whether RIP packets should be broadcast	Choose
Preference for RIP routes	100
Metric for incoming routes	1
Metric for outgoing routes	0
Authentication	None
Update interval	30 seconds

To change RIP parameters, enter the following commands in Configure mode.

Set RIP Version on an interface to RIP V1.	**rip set interface** <*interfacename-or-IPaddr*>**|all version 1**
Set RIP Version on an interface to RIP V2.	**rip set interface** <*interfacename-or-IPaddr*>**|all version 2**
Specify that RIP V2 packets should be multicast on this interface.	**rip set interface** <*interfacename-or-IPaddr*>**|all type multicast**

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Specify that RIP V2 packets that are RIP V1-compatible should be broadcast on this interface.	**rip set interface** <*interfacename-or-IPaddr*>**|all type broadcast**
Change the metric on incoming RIP routes.	**rip set interface** <*interfacename-or-IPaddr*>**|all metric-in** <*num*>
Change the metric on outgoing RIP routes.	**rip set interface** <*interfacename-or-IPaddr*>**|all metric-out** <*num*>
Set the authentication method to simple text up to 8 characters.	**rip set interface** <*interfacename-or-IPaddr*>**|all authentication-method simple**
Set the authentication method to MD5.	**rip set interface** <*interfacename-or-IPaddr*>**|all authentication-method md5**
Specify the metric to be used when advertising routes that were learned from other protocols.	**rip set default-metric** <*num*>
Enable automatic summarization and redistribution of RIP routes.	**rip set auto-summary disable|enable**
Specify broadcast of RIP packets regardless of number of interfaces present.	**rip set broadcast-state always|choose|never**
Check that reserved fields in incoming RIP V1 packets are zero.	**rip set check-zero disable|enable**
Enable acceptance of RIP routes that have a metric of zero.	**rip set check-zero-metric disable|enable**
Enable poison revers, as specified by RFC 1058.	**rip set poison-reverse disable|enable**
Specify the maximum number of RIP routes maintained in the routing information base (RIB). The default is 4.	**rip set max-routes** <*number*>
Disable multipath route calculation for RIP routes.	**rip set multipsth off**

Configuring RIP Route Preference

You can set the preference of routes learned from RIP.

To configure RIP route preference, enter the following command in Configure mode.

Set the preference of routes learned from RIP.	**rip set preference** <*num*>

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13.2.1 Configuring RIP Route Default-Metric

You can define the metric used when advertising routes via RIP that were learned from other protocols. The default value for this parameter is 16 (unreachable). To export routes from other protocols into RIP, you must explicitly specify a value for the default-metric parameter. The metric specified by the default-metric parameter may be overridden by a metric specified in the export command.

To configure default-metric, enter the following command in Configure mode.

Define the metric used when advertising routes via RIP that were learned from other protocols.	**rip set default-metric** *<num>*

For *<num>*, you must specify a number between 1 and 16.

13.3 MONITORING RIP

The *rip trace* command can be used to trace all rip request and response packets.

To monitor RIP information, enter the following commands in Enable mode.

Show all RIP information.	**rip show all**
Show RIP export policies.	**rip show export-policy**
Show RIP global information.	**rip show globals**
Show RIP import policies.	**rip show import-policy**
Show RIP information on the specified interface.	**rip show interface** *<Name or IP-addr>*
Show RIP interface policy information.	**rip show interface-policy**
Show detailed information of all RIP packets.	**rip trace packets detail**
Show detailed information of all packets received by the router.	**rip trace packets receive**
Show detailed information of all packets sent by the router.	**rip trace packets send**
Show detailed information of all request received by the router.	**rip trace request receive**
Show detailed information of all response received by the router.	**rip trace response receive**
Show detailed information of response packets sent by the router.	**rip trace response send**

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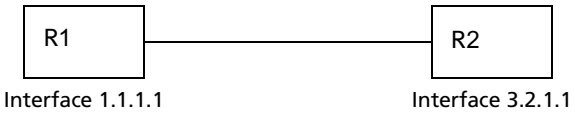
Show detailed information of request packets sent by the router.	**rip trace send request**
Show RIP timer information.	**rip show timers**

13.4 CONFIGURATION EXAMPLE




```
! Example configuration
!
! Create interface R1-if1 with ip address 1.1.1.1/16 on port et.1.1 on
R-1
interface create ip R1-if1 address-netmask 1.1.1.1/16 port et.1.1
!
! Configure rip on R-1
rip add interface R1-if1
rip set interface R1-if1 version 2
rip start
!
!
! Set authentication method to md5
rip set interface R1-if1 authentication-method md5
!
!  Change default metric-in
rip set interface R1-if1 metric-in 2
!
! Change default metric-out
rip set interface R1-if1 metric-out 3
```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14 OSPF CONFIGURATION GUIDE

Open Shortest Path First Routing (OSPF) is a shortest path first or link-state protocol. The RS supports OSPF Version 2.0, as defined in RFC 2328. OSPF is an interior gateway protocol that distributes routing information between routers in a single autonomous system. OSPF chooses the least-cost path as the best path. OSPF is suitable for complex networks with a large number of routers because it provides equal-cost multi-path routing where packets to a single destination can be sent via more than one interface simultaneously.

In a link-state protocol, each router maintains a database that describes the entire AS topology, which it builds out of the collected link state advertisements of all routers. Each participating router distributes its local state (i.e., the router's usable interfaces and reachable neighbors) throughout the AS by flooding. Each multi-access network that has at least two attached routers has a designated router and a backup designated router. The designated router floods a link state advertisement for the multi-access network and has other special responsibilities. The designated router concept reduces the number of adjacencies required on a multi-access network.

OSPF allows networks to be grouped into areas. Routing information passed between areas is abstracted, potentially allowing a significant reduction in routing traffic. OSPF uses four different types of routes, listed in order of preference:

- Intra-area
- Inter-area
- Type 1 ASE
- Type 2 ASE

Intra-area paths have destinations within the same area. Inter-area paths have destinations in other OSPF areas. Both types of Autonomous System External (ASE) routes are routes to destinations external to OSPF (and usually external to the AS). Routes exported into OSPF ASE as type 1 ASE routes are supposed to be from interior gateway protocols (e.g., RIP) whose external metrics are directly comparable to OSPF metrics. When a routing decision is being made, OSPF will add the internal cost to the AS border router to the external metric. Type 2 ASEs are used for exterior gateway protocols whose metrics are not comparable to OSPF metrics. In this case, the external cost from the AS border router to the destination is used in the routing decision.

The RS supports the following OSPF functions:

- Definition of areas, including stub areas and NSSAs (RFC 1587).
- Opaque LSAs (RFC 2370)
- Authentication: Simple password and MD5 authentication methods are supported within an area.
- Configuration of virtual links
- Configuration of parameters at the area, interface or global level. Parameters that can be configured include retransmission interval, interface transmit delay, router priority, router dead and hello intervals, and authentication key.

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- Route Redistribution: Routes learned via RIP, BGP, or any other sources can be redistributed into OSPF. OSPF routes can be redistributed into RIP or BGP. For information on Route Redistribution, refer to Chapter 18, *"Routing Policy Configuration"*.

14.1 OSPF MULTIPATH

The RS also supports OSPF and static Multi-path. If multiple equal-cost OSPF or static routes have been defined for any destination, then the RS "discovers" and uses all of them. The RS will automatically learn up to four equal-cost OSPF or static routes and retain them in its forwarding information base (FIB). The forwarding module then installs flows for these destinations in a round-robin fashion.

14.2 CONFIGURING OSPF

To configure OSPF on the RS, perform the following tasks:

- Set the router ID.
- Enable OSPF
- Create the OSPF area
- Add interfaces to the area
- If necessary, configure virtual links
- Optionally, configure parameters at the global, area, and/or interface level.

14.3 SETTING THE ROUTER ID

The router ID uniquely identifies the RS. To set the router ID to be used by OSPF, enter the following command in Configure mode.

Set the RS' router ID.	**ip-router global set router-id** <*hostname-or-IPaddr*>

If you do not explicitly specify the router ID, then an ID is chosen implicitly by the RS. A secondary address on the loopback interface (the primary address being 127.0.0.1) is the most preferred candidate for selection as the RS' router ID. If there are no secondary addresses on the loopback interface, then the default router ID is set to the address of the first interface that is in the up state that the RS encounters (except the interface en0, which is the Control Module's interface). The address of a non point-to-point interface is preferred over the local address of a point-to-point interface. If the router ID is implicitly chosen to be the address of a non-loopback interface, and if that interface were to go down, then the router ID is changed. When the router ID changes, an OSPF router has to flush all its LSAs from the routing domain.

If you explicitly specify a router ID, then it would not change, even if all interfaces were to go down.

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14.4 ENABLING OSPF

OSPF is disabled by default on the RS.

To enable or disable OSPF, enter one of the following commands in Configure mode.

Enable OSPF.	**ospf start**
Disable OSPF.	**ospf stop**

14.5 CONFIGURING OSPF AREAS

OSPF areas are a collection of subnets that are grouped in a logical fashion. Each area maintains its own link state database. The area topology is known only within the area. A router maintains a separate link state database for each area to which it is connected.

The RS supports the configuration of multiple OSPF areas, as well as three special types of areas:

- backbone - The backbone is responsible for distributing routing information between non-backbone areas. OSPF areas communicate with other areas via the backbone area. The OSPF area backbone contains all area border routers (ABRs).
- stub - A stub area is not used as a transit area. Routers within a stub area route internal traffic only.
- not-so-stubby area (NSSA) - NSSAs are similar to stub areas, except that certain AS external routes may be imported into NSSAs in a limited fashion.

On the RS, you can create multiple OSPF areas, but at least one of them should be an area backbone. To configure an OSPF area, including a stub area or an NSSA, enter the following command in Configure mode. To configure a backbone area, use the **backbone** keyword with the following command.

Create an OSPF area.	**ospf create area** *<area-num>* **|backbone**

After you create an area, you can set its parameters as described in Section 14.9, *"Configuring OSPF Parameters."* To define a stub area, refer to Section 14.5.2, *"Configuring Stub Areas."* To define NSSAs, refer to Section 14.5.3, *"Configuring Not-So-Stubby Areas (NSSA)."*

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14.5.1 Configuring Summary Ranges

To reduce the amount of routing information propagated between areas, you can configure summary-ranges on Area Border Routers (ABRs). On the RS, summary-ranges are created using the **ospf add summary-range** command – the networks specified using this command describe the scope of an area. Intra-area Link State Advertisements (LSAs) that fall within the specified ranges are not advertised into other areas as inter-area routes. Instead, the specified ranges are advertised as summary network LSAs.

Add a network to an OSPF area for summarization.	**ospf add network|summary-range** *<IPaddr-mask>* **to-area** *<area-addr>***| backbone [restrict] [host-net]**

14.5.2 Configuring Stub Areas

Information about routes which are external to the OSPF routing domain is not sent into a stub area. Instead, if the **stub-cost** parameter is specified, the ABR generates a default external route into the stub area for destinations outside the OSPF routing domain. The **stub-cost** specifies the cost to be used to inject a default route into a stub area. If this parameter is not specified, no default route is injected into the OSPF stub area.

To define an OSPF stub area, enter the following command in Configure mode.

Specify an OSPF area to be a stub area.	**ospf set area** *<area-num>* **stub [no-summary][stub-cost** *<num>***]**

The RS provides two ways to reduce the number of summary link advertisements (LSA Type 3) sent into a stub area. To prevent the router from sending any Type 3 LSAs into the stub area, specify the **no-summary** keyword with the **ospf set area** command. This makes the stub area a totally stub area with no Type 3 LSAs going through the stub. Alternatively, you can configure summary filters to filter out specific summary LSAs from the stub area. Use this command for Type 3 LSA you want to block. Type 3 LSAs that are not specified in this command will be sent into the stub area.

To filter specific summary LSAs from a stub area, enter the following command in Configure mode:

Configure summary filters.	**ospf add summary-filters to area** *<area-ID>***|backbone[filter** *<number-or-string>***][network** *<IPaddr-mask>***]|all|default|exact|refines| between** *<number>***|host-net**

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Additionally, there may be interfaces that are directly attached to the router and therefore should be advertised as reachable from the router. To specify an interface that is directly attached, such as a loopback interface, together with its cost, enter the following command in Configure mode..

Add a stub host to an OSPF area.	**ospf add stub-host to-area** *<area-ID>* **|backbone cost** *<num>*

14.5.3 Configuring Not-So-Stubby Areas (NSSA)

NSSAs are similar to stub areas, in that they cannot be used as transit areas. But unlike stub areas, NSSAs can originate and advertise Type-7 LSAs. Type-7 LSAs carry external route information within an NSSA. They are advertised only within a single NSSA; they are not flooded into the backbone area or any other area by border routers. (Type-7 LSAs have the same syntax as Type-5 LSAs, except for the link state type.) In addition, NSSA border routers translate Type-7 LSAs into Type-5 LSAs and flood them to all Type-5 capable areas.

The RS supports the configuration of NSSAs and the ability to add networks to an NSSA. To define an area as an NSSA, enter the following command in Configure mode:

Configures an NSSA.	**ospf set area** *<area-number>* **nssa nssa-cost** *<number>*

- The **nssa-cost** parameter specifies the cost used to inject a default route into an NSSA area. If this parameter is not specified, no default route is injected into the NSSA area.

To add a network to an NSSA area, enter the following command in Configure mode:

Adds an NSSA network to an NSSA.	**ospf add nssa-network** *<IPaddr-mask>* **to area** *<area-addr>* **[restrict][host-net]**

- The **restrict** keyword is used to prevent the network from being advertised in Type 7 LSAs.

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14.6 CONFIGURING OSPF INTERFACES

To configure an interface for OSPF, first configure an IP interface using the **`interface create`** command, then add the interface to an OSPF area. To add an IP interface to an area enter the following command in Configure mode:

Add an interface to an OSPF area.	**`ospf add interface`** *<name-or-IPaddr>* **`to-area`** *<area-addr>* **`|backbone [type broadcast|non-broadcast| point-to-multipoint]`**

When adding the interface to an area, you have the option of specifying the interface type. The Riverstone RS Switch Router can run OSPF over a variety of physical connections: serial connections, LAN interfaces, ATM, or Frame Relay. The OSPF configuration supports four different types of interfaces.

- LAN. An example of a LAN interface is an Ethernet. The RS will use multicast packets on LAN interfaces to reach other OSPF routers. By default, an IP interface attached to a VLAN that contains LAN ports is treated as an OSPF broadcast network. To add this type of interface to an area, use the **`type broadcast`** option with the **`ospf add interface`** command.
- Point-to-Point. A point-to-point interface can be a serial line using PPP. By default, an IP interface associated with a serial line that is using PPP is treated as an OSPF point-to-point network. For additional information on configuring this type of interface, refer to Section 14.6.3, *"Configuring Interfaces for Point-to-Point Networks."*
- Non-Broadcast Multiple Access (NBMA). An example of an NBMA network is a fully-meshed Frame Relay or ATM network with virtual circuits. To add this type of interface, use the **`type non-broadcast`** option of the **`ospf add interface`** command. For additional information on configuring this type of interface, refer to Section 14.6.1, *"Configuring Interfaces for NBMA Networks."*
- Point-to-Multipoint (PMP). Point-to-multipoint connectivity is used when the network does not provide full connectivity to all routers in the network. To add this type of interface, use the **`type point-to-multipoint`** option of the **`ospf add interface`** command. For additional information on configuring this type of interface, refer to Section 14.6.2, *"Configuring Interfaces for Point-to-Multipoint Networks."*

14.6.1 Configuring Interfaces for NBMA Networks

Because there is no general multicast for these networks, each neighboring router that is reachable over the NBMA network must be specified, so that routers can poll each other. The RS unicasts packets to other routers in the NBMA network.

To specify a neighboring router that is reachable over the NBMA network, enter the following command in Configure mode:

Specify an OSPF NBMA neighbor.	**`ospf add nbma-neighbor`** *<hostname-or-IPaddr>* **`to-interface`** *<name-or-IPaddr>* **`[eligible]`**

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14.6.2 Configuring Interfaces for Point-to-Multipoint Networks

As in the case of NBMA networks, a list of neighboring routers reachable over a PMP network should be configured so that the router can discover its neighbors.

To specify a reachable neighbor on a point-to-multipoint network, enter the following command in Configure mode:

Specify an OSPF point-to-multipoint neighbor.	**ospf add pmp-neighbor** <*IPaddr*> **to-interface** <*name-or-IPaddr*>

14.6.3 Configuring Interfaces for Point-to-Point Networks

By default, OSPF packets are multicast to neighbors on an OSP point-to-point network. If an IP interface that is using PPP is to be treated as an OSPF broadcast network, then use the **type broadcast** option of the **ospf add interface** command. But if a remote neighbor does not support multicasting and you would like to unicast OSPF packets, enter the following command in Configure mode:

Force point-to-point interfaces to unicast OSPF packets.	**ospf set interface** <*name-or-IPaddr*> **no-multicast**

14.7 CONFIGURING OSPF INTERFACE PARAMETERS

The RS provides a number of parameters that are set at the interface level. To set OSPF interface parameters, enter the following command in Configure mode:

Set OSPF interface parameters.	**ospf set interface** <*name-or-IPaddr*> **|all [state disable|enable][cost** <*num*>**][no-multicast] [retransmit-interval** <*num*>**][transit delay** <*num*>**] [priority** <*num*>**][hello-interval**<*num*>**] [router-dead-interval**<*num*>**][poll-interval**<*num*>**] [key-chain** <*num*>**][authentication-method none|simple|md5][advertise subnet on|off] [passive]**

This section describes parameters that are of special significance to interfaces. For information about parameters that can be set globally, refer to Section 14.9, *"Configuring OSPF Parameters."*

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14.7.1 Setting the Interface State

OSPF interfaces that are added to an area are enabled by default. You can disable them by using the **`state disable`** option with the **`ospf set interface`** command.

14.7.2 Setting the Default Cost of an OSPF Interface

The RS calculates the default cost of an OSPF interface using the reference bandwidth and the interface bandwidth. The default reference bandwidth is 1000. It can be changed by using the **`ospf set ref-bwdth`** command.

A VLAN that is attached to an interface could have several ports of differing speeds. The bandwidth of an interface is represented by the highest bandwidth port that is part of the associated VLAN. The cost of an OSPF interface is inversely proportional to this bandwidth. The cost is calculated using the following formula:

Cost = reference bandwidth * 1,000,000/ *interface bandwidth (in bps)*

The following is a table of the port types and the OSPF default cost associated with each type:

Table 14-1 OSPF default cost per port type

Port Media Type	Speed	OSPF Default Cost
Ethernet 1000	1000 Mbps	2
Ethernet 10/100	100 Mbps	20
Ethernet 10/100	10 Mbps	200
WAN (T1)	1.5 Mbps	1333
WAN (T3)	45 Mbps	44

14.8 CREATING VIRTUAL LINKS

In OSPF, virtual links can be established:

- To connect an area via a transit area to the backbone
- To create a redundant backbone connection via another area

Each ABR must be configured with the same virtual link. Note that virtual links cannot be configured through a stub area.

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To configure virtual links, enter the following commands in the Configure mode.

Create a virtual link.	**ospf add virtual-link** *<number-or-string>* **neighbor** *<IPaddr>* **transit-area** *<area-id>*
Set virtual link parameters.	**ospf set virtual-link** *<number-or-string>* **[state disable|enable] [cost** *<num>***] [retransmit-interval** *<num>***] [transit-delay** *<num>***] [priority** *<num>***] [hello-interval** *<num>***] [router-dead-interval** *<num>***] [poll-interval** *<num>***] [key-chain** *<num>***] [authentication-method none|simple|md5] [no-multicast]**

Note For information on the virtual link parameters, refer to the next section, Section 14.9, *"Configuring OSPF Parameters."*

14.9 CONFIGURING OSPF PARAMETERS

The RS provides several parameters that can be set at the global (router) level, at the area level, and at the interface level. Parameters set at the interface level take precedence over those set at the area level, and parameters set at the area level take precedence over "global" parameters. The following table lists the parameters that can be set at all three levels.

Parameter	Description
advertise-subnet	Indicates whether the point-to-point interface will be advertised as a subnet.
authentication method	Specifies the authentication method used within the area.
hello-interval	Specifies the length of time between the transmission of hello packets.
poll-interval	Specifies the interval at which OSPF packets will be sent, before an adjacency is established with a neighbor.
priority	Specifies the router's priority during the Designated Router election.
retransmit-interval	The interval between LSA retransmissions.

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Parameter	Description
router-dead interval	The interval the router waits after receiving no Hello packets from its neighbor before considering it as down.
transit delay	The estimated time it takes to transmit an LSA update.

14.9.1 Configuring OSPF Global Parameters

The following sections describe parameters that can be set only at the global level.

Configuring the Routing Table Recalculation

The default interval between the recalculation of the routing table is 5 seconds. You can change this interval, if necessary. Increasing the interval allows more time wherein routing changes can occur. Or, you can set it to 0, for the recalculation to occur immediately, one after the other.

To configure the interval between routing table recalculations, enter the following command in Configure mode:

Set the interval between routing table recalculations.	**ospf set spf-holdtime** <*number*>

Configuring Autonomous System External (ASE) Link Advertisements

Because of the nature of OSPF, the rate at which ASEs are flooded may need to be limited. The following parameters can be used to adjust those rate limits. These parameters specify the defaults used when importing OSPF ASE routes into the routing table and exporting routes from the routing table into OSPF ASEs.

To specify AS external link advertisements parameters, enter the following commands in Configure mode:

Specifies how often a batch of ASE link state advertisements will be generated and flooded into OSPF. The default is 1 time per second.	**ospf set export-interval** <*num*>

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Specifies how many ASEs will be generated and flooded in each batch. The default is 250.	**ospf set export-limit** <*num*>
Specifies AS external link advertisement default parameters.	**ospf set ase-defaults [preference** <*num*>**]| [cost** <*num*>**]|[type** <*num*>**] | [inherit-metric] [tag** <*num*>**] [as}**

Configuring Support for Opaque LSAs

The RS supports opaque LSAs as defined in RFC 2370. This ability is turned off by default because it can enlarge the link state database unnecessarily.

To turn on support for RFC 2370 opaque LSAs, enter the following command in Configure mode:

Enables the processing of opaque LSAs on the RS.	**ospf set opaque-capability on|off**

Setting Route Preference

Preference is the value the RS routing process uses to determine the order of routes to the same destination in a single routing database. The active route is chosen by the lowest preference value.

A default preference is assigned to each source from which the RS routing process receives routes. The default preference value for OSPF routes is 10. You can change the default preference by entering the following command in Configure mode:

Set the preference value for routes learned from OSPF.	**ospf set preference** <*number*>

For additional information on how the RS uses preference values, refer to Chapter 18, *"Routing Policy Configuration"*.

Setting the Reference Bandwidth

The RS uses the reference bandwidth to calculate the cost of an OSPF interface. The default reference bandwidth is 1000. You can change this value by entering the following command in Configure mode:

Set the reference bandwidth.	**ospf set ref-bwdth** <*number*>

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14.10 MONITORING OSPF

The Riverstone RS Switch Router provides two different command sets to display the various OSPF tables:

- **`ospf monitor`** commands allow you to display the OSPF tables for the router on which the commands are being entered, as well as for other remote Riverstone RS Switch Routers running OSPF. The **`ospf monitor`** commands can be used to display a concise version of the various OSPF tables. All of the **`ospf monitor`** commands accept a **`destination`** option. This option is only required to display the OSPF tables of a remote Riverstone RS Switch Router.
- **`ospf show`** commands allow you to display detailed versions of the various OSPF tables. The **`ospf show`** commands can only display OSPF tables for the router on which the commands are being entered.

Following are some examples of the **`ospf monitor`** and **`ospf show`** commands.

Following is an example of the **`ospf monitor interfaces`** command. Information reported includes the area ID, interface IP address, interface type, interface state, cost, priority, and IP addresses of the designated router and backup designated router for the network.

```
rs# ospf monitor interfaces
Area: 190.135.89
IP Address      Type  State    Cost Pri DR              BDR
-------------------------------------------------------------------------
100.1.1.1       Bcast DR       20   1   7.7.7.7         0.0.0.0
73.1.1.1        PtoP  Pt2Pt    3    1   0.0.0.0         0.0.0.0
33.33.33.33     Bcast DR       20   1   7.7.7.7         0.0.0.0
190.135.89.227  Bcast Back DR  20   1   1.1.1.1         7.7.7.7
190.135.89.33   Bcast DR       20   1   7.7.7.7         0.0.0.0
```

Following is an example of the **`ospf show areas all`** command. It displays information about the interfaces in the area and the area's link state database.

```
Area 190.135.89

    Transit Capability: 0
    Area Border Routers: 2
    AS Border Routers: 0
    Spf count: 42
    Local Virtual Links: 0
    Router Vertex: 81d509a0
    Default Summary Vertex: 0

    No Configured Stub Links

    No network summariziation ranges

    No active tree walks

    Interfaces:
 Internet Address 100.1.1.1/24, Area 190.135.89
                Router ID 7.7.7.7, Network Type Broadcast, Cost: 20
                Transmit Delay is 1 sec, State DR, Priority 1
                Designated Router (ID) 7.7.7.7, Interface address 100.1.1.1
                No backup designated router on this network
                Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
                    Hello due in 14:58:33
```


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Following is an example of the **`ospf show statistics interface`** command. It displays the number of each type of LSA that was processed.

```
rs# ospf show statistics interface 190.135.89.227

Statistics for Interface 190.135.89.227:

Packets Received:
 Monitor                            0   Hello                            366
 Database Desciption                4   LS Request                         1
 LS Update                         14   LS Acknowledgement                 3

Packets Sent:
 Monitor                            0   Hello                            365
 Database Desciption                3   LS Request                         1
 LS Update                          3   LS Acknowledgement                14

Errors:
 Packet too short                   0
 Invalid header lengh               0   Invalid version                    0
 Invalid checksum                   0   Invalid authentication type        0
 No such multicast interface        0   No such interface                  0
 Invalid interface                  0   Invalid Mask                       0
 Invalid Hello interval             0   Invalid Router Dead interval       0
 Unknown neighbour                  0   Options mismatch                   0
 Master flag mismatch               0   Initialize flag mismatch           0
 DD sequence number mismatch        0   Invalid LS type                    0
 Bad LS Request                     0   No such virtual interface          0
 Invalid area ID                    0   Confusing Master/Initial flags     2
 Invalid MD5 digest                 0   Own packet received                0
 Invalid authentication key         0   DD Options mismatch                0
 Packet on passive interface        0   Packet on down virtual interface   0
 Packet with same router id as ours 0
```

Following is an example of the **`ospf show virtual-links`** command:

```
rs# ospf show virtual-links
Internet Address 2.2.2.2, Transit Area 201.135.89
    Router ID 3.3.3.3, Network Type Virtual, Cost: 20
    Transmit Delay is 1 sec, State Pt2Pt, Priority 1
    Designated Router (ID) 0.0.0.0, Interface address 2.2.2.2
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 15:39:53
    Neighbor Count is 1

Internet Address 4.4.4.4, Transit Area 201.135.89
    Router ID 3.3.3.3, Network Type Virtual, Cost: 1
    Transmit Delay is 1 sec, State Down, Priority 1
    Designated Router (ID) 0.0.0.0, Interface address 4.4.4.4
    No backup designated router on this network
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Neighbor Count is 0
```


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Note For additional information on the sample output and the other **`ospf monitor`** and **`ospf show`** commands, refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

14.11 OSPF CONFIGURATION EXAMPLES

For all examples in this section, refer to the configuration shown in Figure 14-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.90.1.2
 ip add route 160.1.5.0/24 gateway 120.90.1.2
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Box Level Configuration
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Interface Configuration
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```


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14.11.1 Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We will export these static routes as type-2 OSPF routes. The interface routes will be redistributed as type-1 OSPF routes.

1. Create a nOSPF export destination for type-1 routes to redistribute certain routes into OSPF as type 1 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```

2. Create an OSPF export destination for type-2 routes to redistribute certain routes into OSPF as type 2 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

3. Create a Static export source to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

4. Create a Direct export source to export interface/direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy for redistributing all interface routes and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
```

14.11.2 Exporting All RIP, Interface & Static Routes to OSPF

We will also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 14-1, RIP Version 2 is configured on the interfaces of routers R1 and R2, which are attached to the sub-network 120.190.0.0/16.

We will redistribute these RIP routes as OSPF type-2 routes and associate the tag 100 with them. Router R1 will also redistribute its static routes as type 2 OSPF routes. The interface routes will be redistributed as type 1 OSPF routes.

Router R1 will redistribute its OSPF, OSPF-ASE, RIP, Static and Interface/Direct routes into RIP.

1. Enable RIP on interface 120.190.1.1/16.

```
rip add interface 120.190.1.1
rip set interface 120.190.1.1 version 2 type multicast
```

2. Create an OSPF export destination for type-1 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type
    1 metric 1
```


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3. Create an OSPF export destination for type-2 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type
    2 metric 4
```

4. Create an OSPF export destination for type-2 routes with a tag of 100.

```
ip-router policy create ospf-export-destination ospfExpDstType2t100
    type 2 tag 100 metric 4
```

5. Create a RIP export source.

```
ip-router policy create rip-export-source ripExpSrc
```

6. Create a Static export source.

```
ip-router policy create static-export-source statExpSrc
```

7. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy for redistributing all interface, RIP and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source
    directExpSrc network all
ip-router policy export destination ospfExpDstType2 source
    statExpSrc network all
ip-router policy export destination ospfExpDstType2t100 source
    ripExpSrc network all
```

9. Create a RIP export destination.

```
ip-router policy create rip-export-destination ripExpDst
```

10. Create OSPF export source.

```
ip-router policy create ospf-export-source ospfExpSrc type OSPF
```

11. Create OSPF-ASE export source.

```
ip-router policy create ospf-export-source ospfAseExpSrc type
    OSPF-ASE
```


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12. Create the Export-Policy for redistributing all interface, RIP, static, OSPF and OSPF-ASE routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc
    network all
ip-router policy export destination ripExpDst source ripExpSrc
    network all
ip-router policy export destination ripExpDst source directExpSrc
    network all
ip-router policy export destination ripExpDst source ospfExpSrc
    network all
ip-router policy export destination ripExpDst source ospfAseExpSrc
    network all
```


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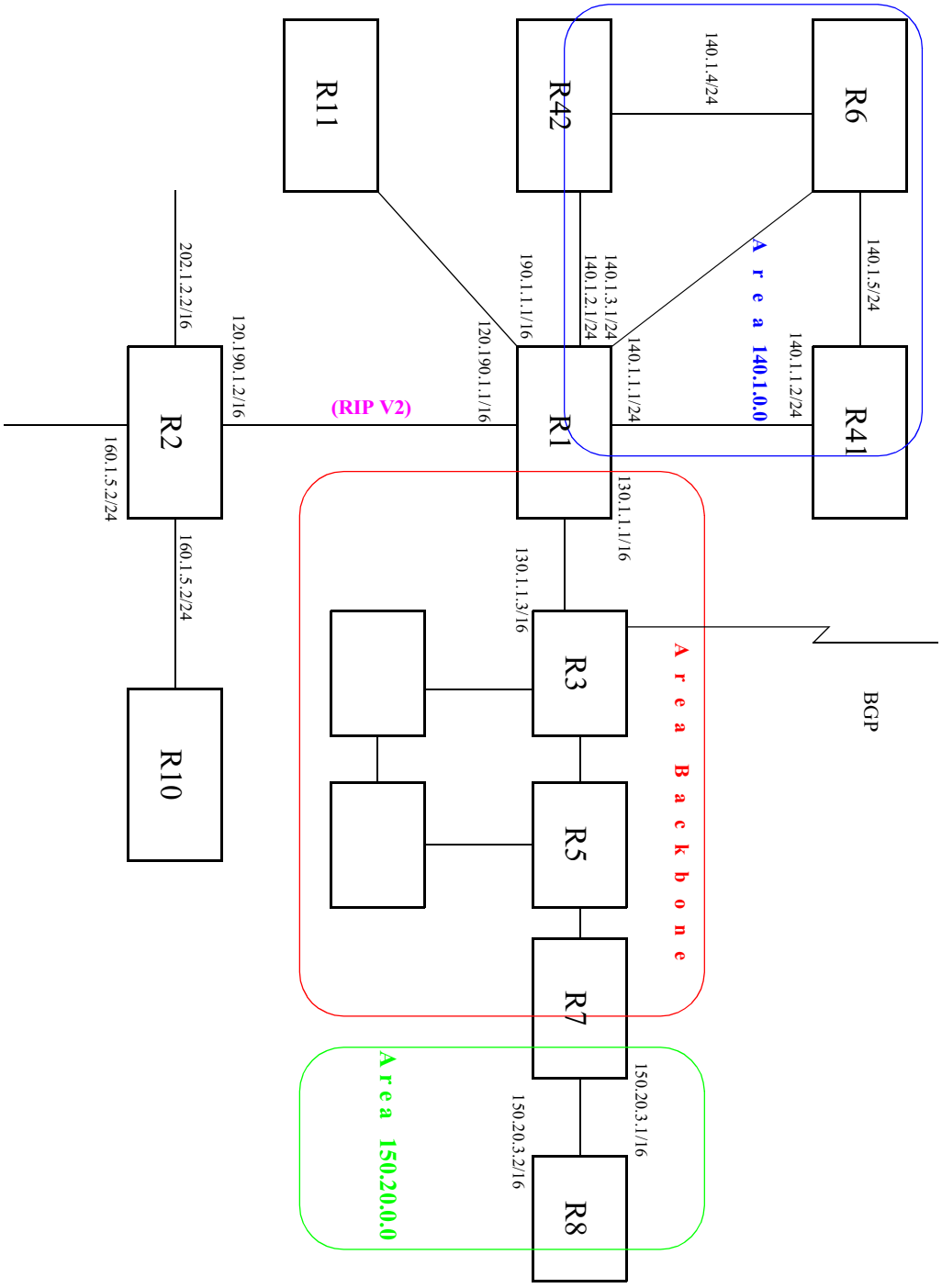

Figure 14-1 Exporting to OSPF

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15 IS-IS CONFIGURATION GUIDE

This chapter provides an overview of the Intermediate System-Intermediate System (IS-IS) routing protocol features available for the Riverstone RS Switch Router.

IS-IS is a link state hierarchical routing protocol. In IS-IS, a router is an Intermediate System (IS), and a routing sub domain is an area. An IS-IS area can contain a number of routers and end devices. Routing within an area is handled by Level 1 routers, and routing between different areas is handled by Level 2 routers. An IS can route Level 1 and/or Level 2 traffic.

The IS-IS routing protocol is based on "shortest path first" calculations, similar to the OSPF routing protocol. Intermediate Systems exchange link state information by transmitting Link State Protocol Data Units (LSPs). (LSPs are exchanged between same level routers only.) Each IS maintains its own LSP database.

To configure the RS to run IS-IS, you should perform the following tasks:

- Define the area to which the router will belong.
- Configure IS-IS interfaces.
- Start IS-IS.

Optionally, you can modify the default IS-IS parameters that are set globally and on a per-interface basis.

15.1 DEFINING AN IS-IS AREA

An IS-IS area is a network sub domain that consists of routers and the end devices connected to them. All routers in an area maintain detailed routing information about destinations within the area. When you define the area of the RS, all its interfaces belong to that area. Interfaces on an RS cannot belong to separate areas.

To define the IS-IS area to which the RS will belong, enter the following command in Configure mode:

Defines an IS-IS area.	**isis add area** <*string*>

15.2 CONFIGURING IS-IS INTERFACES

IS-IS is disabled on all RS interfaces by default. To enable IS-IS on an interface, first configure an IP interface using the **interface create** command. Then, enable IS-IS on the interface. You can enable IS-IS on all IP interfaces by specifying the **all** keyword.

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To enable IS-IS on an interface, enter the following command in Configure mode:

Creates an IS-IS interface on a router.	**isis add interface** <*string*>**|all**

15.3 ENABLING IS-IS ON THE RS

IS-IS is disabled on the RS by default. To enable IS-IS on the RS, enter the following command in Configure mode:

Enables IS-IS on the router.	**isis start**

15.4 SETTING IS-IS GLOBAL PARAMETERS

The RS provides global IS-IS parameters which control the router's operating level, timers, authentication, and other IS-IS functions. The following sections discuss the global IS-IS parameters that you can modify to better suit your routing environment.

15.4.1 Setting the IS Operating Level

An IS can be configured to route Level 1 and/or Level 2 traffic. Level 1 routing handles all intra-domain traffic, (all traffic within an IS-IS area). Level 2 routing handles all inter-domain traffic (all traffic between different IS-IS areas).

On the RS, you can set the operating level for the router and on a per-interface basis. The default level for both the router and its interfaces is Level 1- and-2. You may change the default for either or both. If you do so, keep in mind that the operating level of the interfaces must agree with the operating level of the RS. Therefore if a router's operating level is set to Level 1 or to Level 2, its interfaces should be set to the same level. But if the interfaces will be routing both Level 1 and Level 2 traffic, then you should set the router's level to Level 1-and-2.

To set the router's operating level, enter the following command in Configure mode:

Sets the IS-IS level for a router.	**isis set level 1|2|1-and-2**

15.4.2 Setting the PSN Interval

On point-to-point subnetworks, an IS sends a Partial Sequence Number PDU (PSNP) to acknowledge each LSP it receives. PSNPs contain the following information: LSP ID, the LSP's sequence number, the LSP's Checksum and the LSP's Remaining Lifetime.

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To set the time interval between PSNP transmissions, enter the following command in Configure mode:

Sets the PSNP interval.	**isis set psn-interval** <*number*>

15.4.3 Setting the System ID

A system ID is a unique 12 hexadecimal number that uniquely identifies the IS in the routing domain. A system ID is assigned to the IS by default, but can be overwritten using the following command.

To set the system ID for an IS, enter the following command in Configure mode:

Sets the system ID for a router.	**isis set system-id** <*string*>

Note that once the system ID is set, it cannot be changed without disabling and reenabling IS-IS.

15.4.4 Setting the SPF Interval

The spf interval is the time period between route table recalculations. The default is 2 seconds. Increasing the spf interval allows time for more changes to occur before the recalculation.

To set a router's spf interval, enter the following command in Configure mode:

Sets the router's spf interval.	**isis set spf-interval** <*number*>

15.4.5 Setting the Overload Bit

The IS-IS protocol provides a feature for routers to signal each other when they cannot record the complete LSP database. (This occurs when a router has run out of memory.) When a router experiences memory overload, it sets its overload bit in its LSPs. The other routers will then route packets to that router's directly connected networks, but will not use it to route transit traffic until its overload bit is cleared. In the RS, you can manually set the router's overload bit so it functions only as an end system.

To set the router's overload bit, enter the following command in Configure mode:

Sets the overload bit.	**isis set overload-bit**

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15.4.6 Setting IS-IS Authentication

The RS supports four levels of authentication for IS-IS: authentication between neighbors, within an area, within a domain, and authentication of SNPs. The first three levels of authentication can use either MD5 or simple authentication. (For additional information about these authentication methods, refer to Chapter 18.1.5, *"Authentication."*) The following sections describe each level of authentication.

Authentication Between Neighbors

This level of authentication controls the exchange of hello packets between neighbors. All Level 1 interfaces should use the same method of authentication, and all Level 2 interfaces should use the same authentication method. If connecting interfaces have different types of authentication, they will not be able to exchange hello packets or form adjacencies.

To specify the authentication method between neighbors, enter the following command in Configure mode:

Sets the authentication method for the interface.	**isis set interface** <*string*> **authentication-method md5|simple key-chain** <*string*>

Authentication Within an Area

This level of authentication controls the exchange of Level 1 LSPs. Routers which do not have the same authentication at this level will be able to form adjacencies, but *will not* be able to exchange Level 1 LSPs. To configure authentication within an area, enter the following command in Configure mode:

Sets the authentication method for an area.	**isis set area-key-chain** <*string*> **authentication-method none|md5|simple**

Authentication Within a Routing Domain

This type of authentication controls the exchange of LSPs between areas. Routers which do not have the same authentication at this level will not be able to exchange Level 2 LSPs. To configure authentication within a routing domain, enter the following command in Configure mode:

Sets the authentication method for a routing domain.	**isis set domain-key-chain** <*string*> **authentication-method none|md5|simple**

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SNP Authentication

This type of authentication controls the processing of SNPs (both CSNPs and PSNPs). When the router receives an SNP, it authenticates it by checking the password (which is the same as the password set using the **isis set interface password** command).

To configure SNP authentication, enter the following command in Configure mode:

Sets authentication for SNPs.	**isis set require-snp-auth**

15.5 SETTING IS-IS INTERFACE PARAMETERS

The interfaces on the RS have default IS-IS parameter values. These parameters control various IS-IS functions and features on the interfaces, such as their operating level, metrics, and timers.

To set parameters for an IS-IS interface, enter the following command in Configure mode:

Configures an IS-IS interface on a router.	**isis set interface** <*interface-name-or IPaddr*> **[level 1|2|1-and-2] [metric** <*number*>**] [priority** <*number*>**] [hello-interval** <*number*>**] [dis-hello-interval** <*number*>**] [hello-multipler** <*number*>**] [csn-interval** <*number*>**] [lsp-interval**<*number*>**] [max-burst** <*number*>**] [passive] [retransmit-interval** <*number*>**] [authentication-method none|md5|simple] [key-chain** <*string*>**] [l1-csn-interval** <*number*>**] [l1-dis-hello-interval**<*number*>**] [l1-hello-interval** <*number*>**] [l1-hello-multipler** <*number*>**] [l1-metric** <*number*>**] [l1-priority** <*number*>**] [l2-csn-interval** <*number*>**] [l2-dis-hello-interval**<*number*>**] [l2-hello-interval** <*number*>**] [l2-hello-multipler** <*number*>**] [l2-metric** <*number*>**] [l2-priority** <*number*>**][mesh-group]**<*number*>

The following sections describe some of the parameters used by the IS-IS interfaces. For a detailed description of this command and its parameters, refer to the **isis commands** chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

15.5.1 Setting the Interface Operating Level

The default operating level for the router and its interfaces is Level 1-and-2. If you change the default, note that the operating level of the router's IS-IS interfaces should be synchronized with the operating level of the router. (For additional information, refer to Section 15.4.1, *"Setting the IS Operating Level,"*.)

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15.5.2 Setting Interface Parameters for a Designated Intermediate System (DIS)

On a broadcast network, routers elect a DIS, which advertises all links to the attached routers. The following parameters are used during DIS election and by the interface, if it is elected as the DIS. These parameters can be set globally, or for Level-1 or Level-2 interfaces only.

- Priority
  The router's priority for the Designated Intermediate System (DIS) election. The router with the highest priority becomes the DIS. To ensure that a router does not become the DIS, set this parameter to 0. To increase a router's chance of becoming a DIS, set this parameter to the highest value, which is 127. In case of a tie, the router with the highest System ID becomes the DIS. To The default priority is 1.
- DIS Hello Interval
  The hello-interval used if the router becomes the DIS. The default hello-interval is 3.
- CSN Interval
  The interval at which the router will multicast Complete Sequence Number PDUs (CSNPs), if the router becomes the DIS. CSNPs contain a list of all LSPs in the database in addition to information used by the other routers to determine whether they have synchronized LSP databases. The default csn-interval is 10.

15.5.3 Setting IS-IS Interface Timers

The IS-IS protocol uses a variety of timers, some of which can be modified at the interface level. The timers have default values which you can change when needed. These are as follows:

- Hello Interval
  The interval at which hello packets are sent.
- Hello Multiplier
  The number of hello-intervals a router does not receive a hello-packet from its neighbor before it considers its neighbor as down.
- LSP Interval
  The interval between the transmission f LSPs.
- Retransmit Interval
  The interval a router waits before it retransmits an LSP.

15.5.4 Setting Mesh Group Membership

The **mesh-group** parameter allows for the assignment of interfaces to *mesh groups,* as defined in RFC 2973. Mesh groups are used within full-mesh, point-to-point topologies to limit the amount of flooding of LSPs. Each interface in a particular mesh group will not forward an LSP if the LSP is received on a port that belongs to that mesh group. Mesh groups are identified by numbers, and range from 0 to 2147483647. Assigning an interface to mesh group 0 (zero), sets that interface to not forward any LSPs, regardless of the interface on which it is received.

The following is an example of assigning a set of interfaces to mesh groups:

```
rs(config)# isis set interface gig1 mesh-group 10
rs(config)# isis set interface gig2 mesh-group 10
rs(config)# isis set interface gig3 mesh-group 10
rs(config)# isis set interface gig4 mesh-group 0
```


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In the example above, interfaces **gig1** through **gig3** will not forward an LSPs if the LSP is received by any interface in mesh group 10. Additionally, interface **gig4** will not forward an LSP, regardless of the interface on which it is received.

15.6 DISPLAYING IS-IS INFORMATION

The RS provides a number of commands which you can use to view information about your IS-IS configuration. The **isis show all** command displays all the router's IS-IS tables. Individual tables may also be viewed using the commands in the following table.

Displays IS-IS adjacencies.	**isis show adjacencies [detail]**
Displays information about the other router on the circuit.	**isis show circuits [detail]**
Displays IS-IS export policies.	**isis show export-policies**
Displays IS-IS global parameters.	**isis show globals**
Displays Link State PDU (LSP) database information.	**isis show lsp-database level1|2 [detail][id**<*string*>**][summary]**
Displays IS-IS timers.	**isis show timers**

Note For additional information about the **isis show** commands, their parameters, or the fields in the output, refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

15.6.1 IS-IS Sample Configuration

Consider the following network configuration. The network shown consists of 11 routers subdivided into four IS-IS areas.

Figure 15-1 shows the network topology. Figures 11 through 14 provide a detailed illustration of each area.

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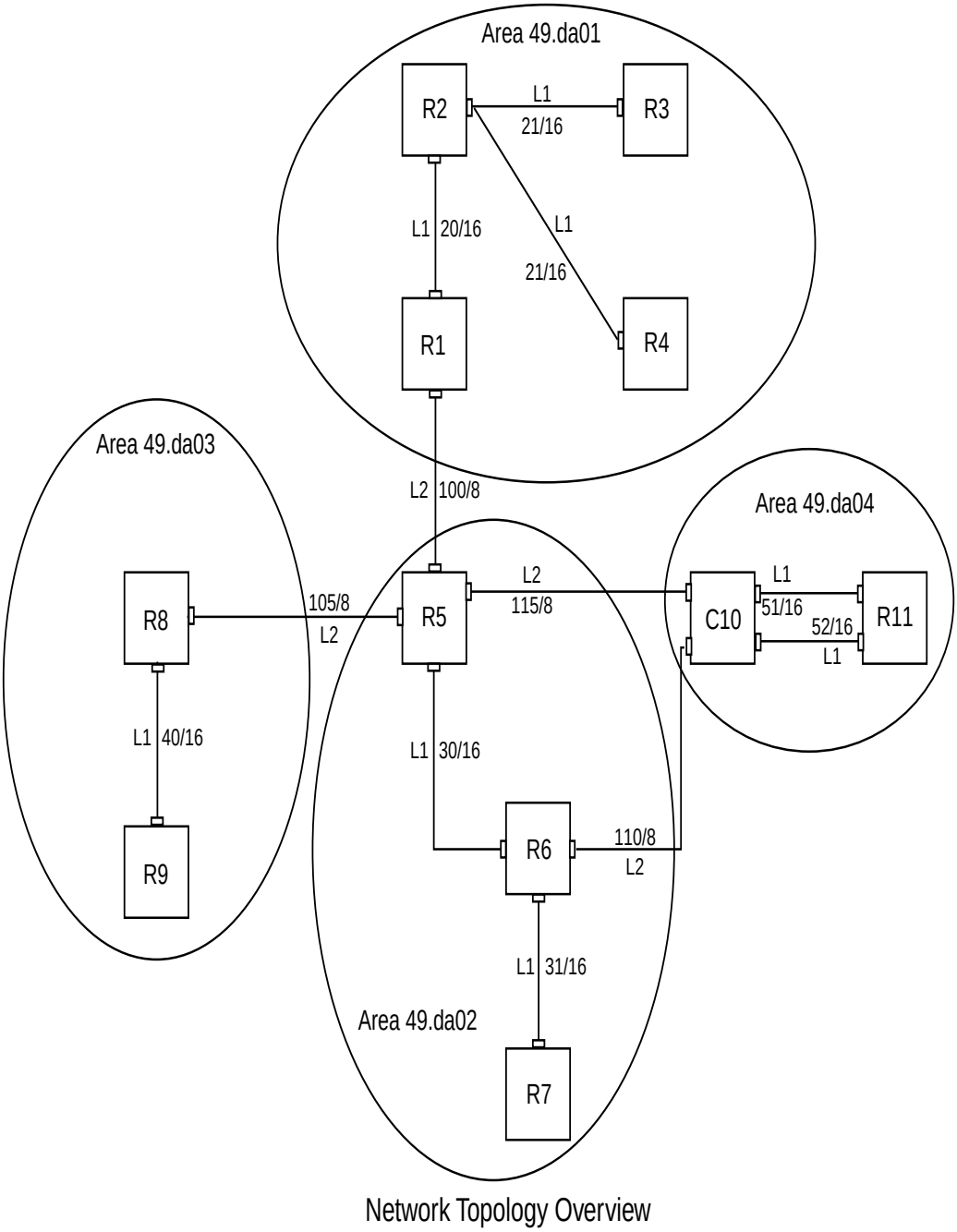

Figure 15-1 Network overview

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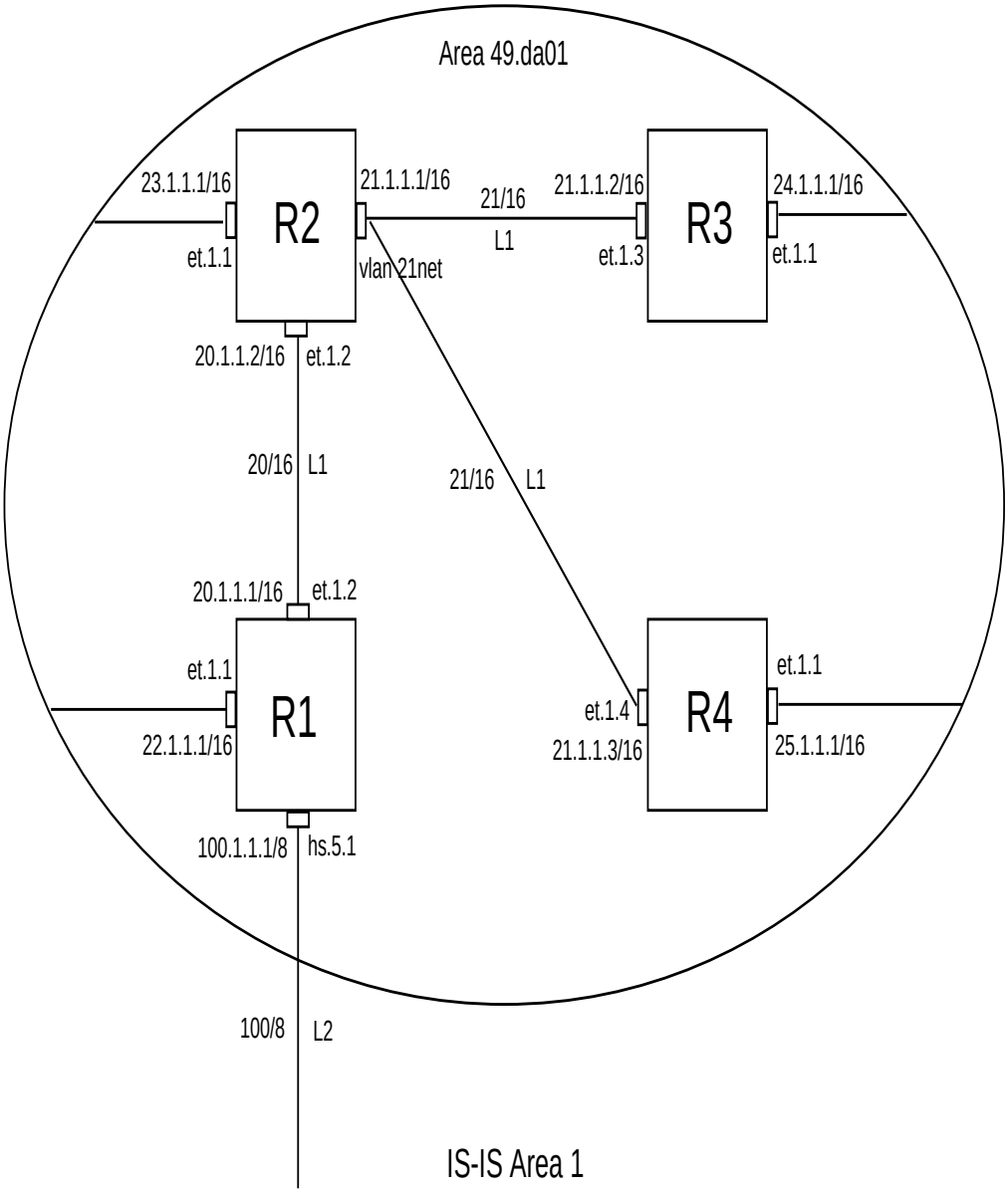

Figure 15-2 Area 1 detailed view

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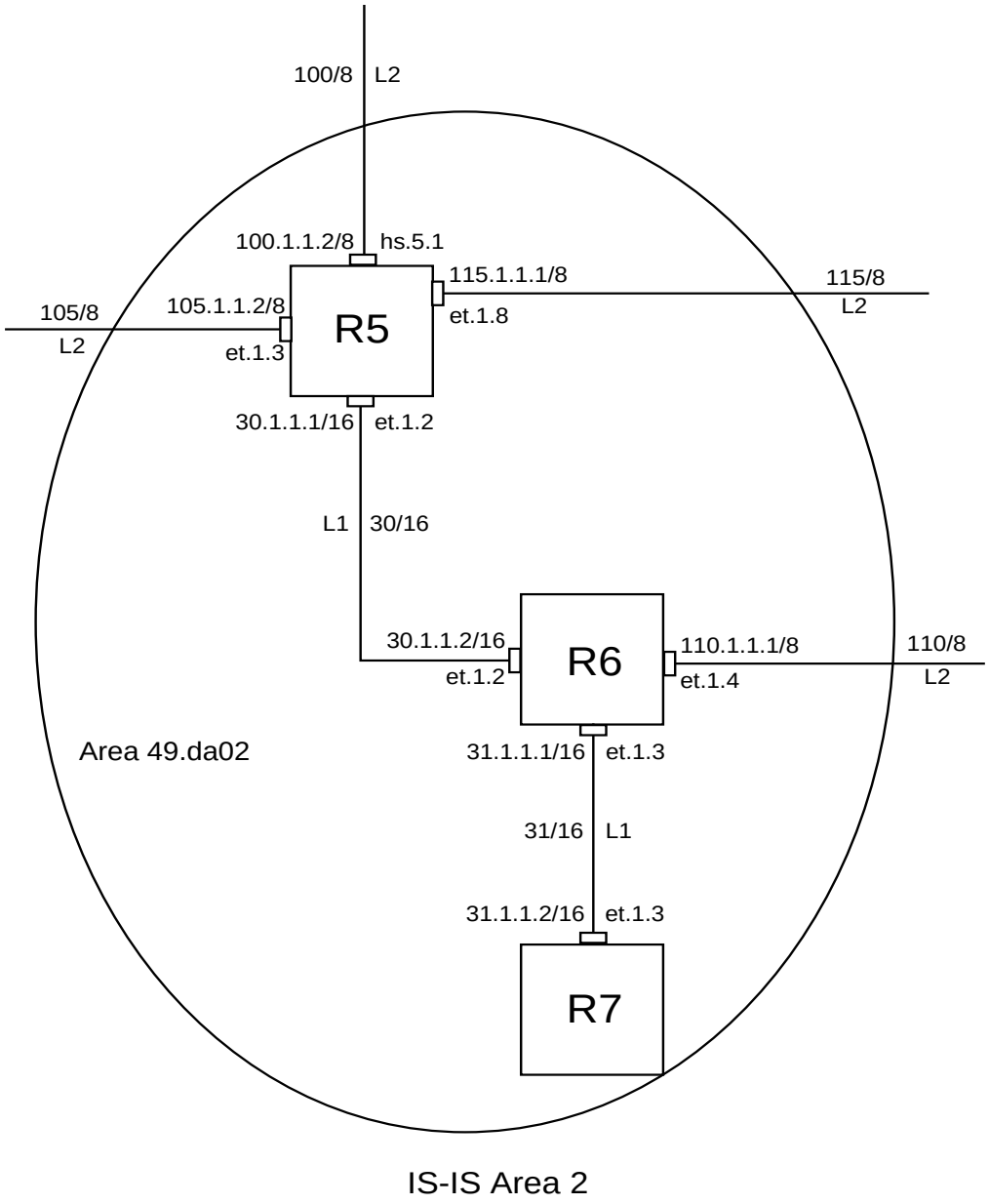

Figure 15-3 Area 2 detailed view

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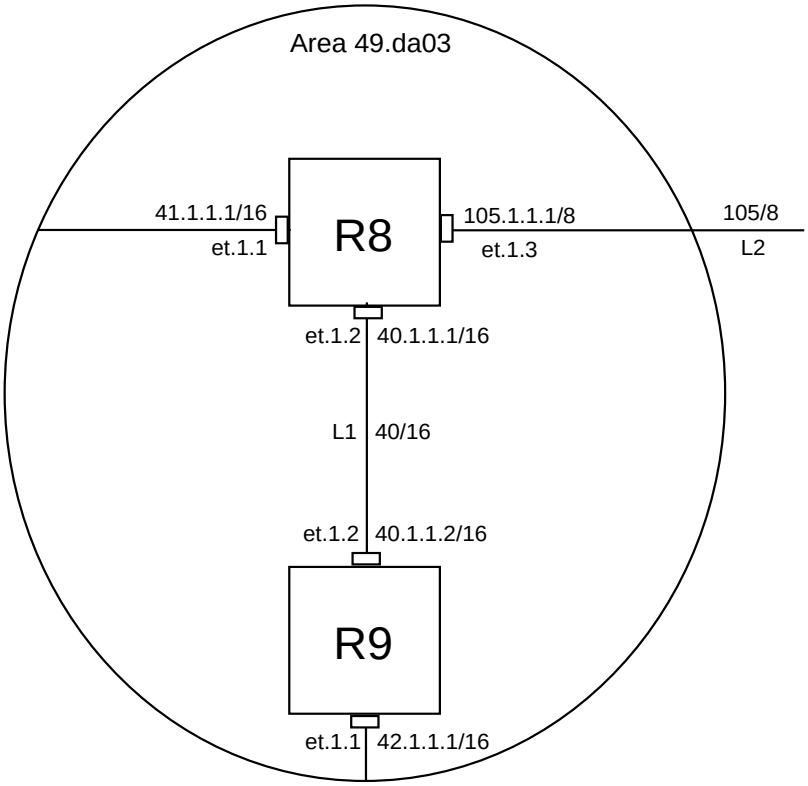

Figure 15-4 Area 3 detailed view

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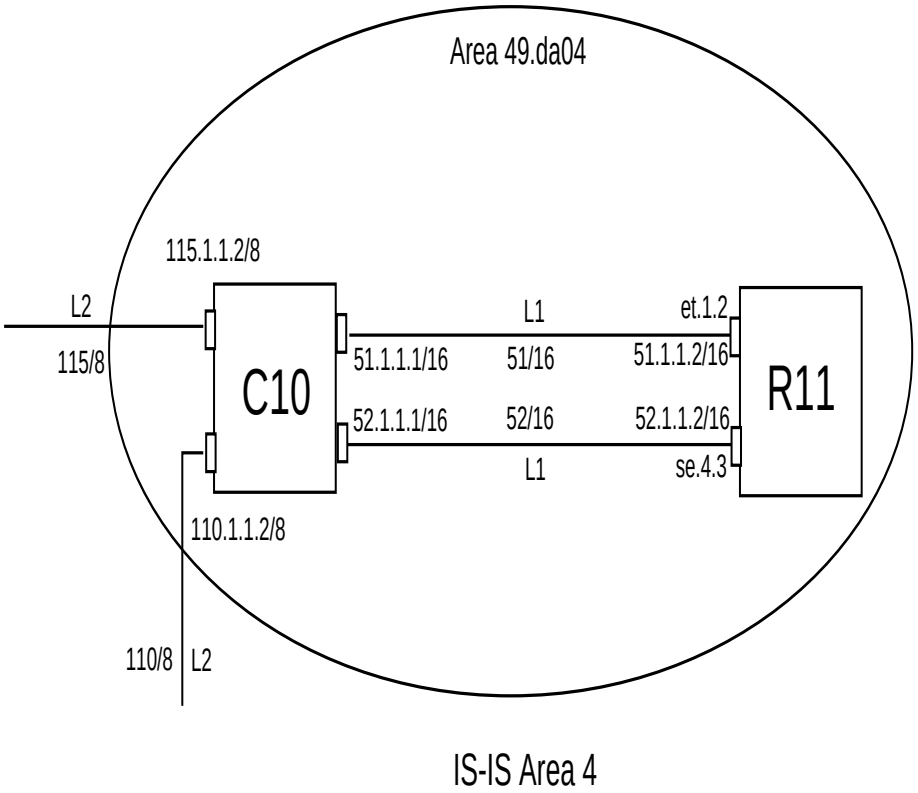

Figure 15-5 Area 4 detailed view

The following sections show the configuration for each router within this network. Note that explanations (in *italics*) precede each command or set of commands.

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R1 Configuration

The following is the configuration for R1 in Area 1. R1 has a Level 1 IS-IS interface and a Level 2 IS-IS interface.

```
R1(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-29 12:13:03
     !
To configure the WAN port hs.5.1:
 1 : port set hs.5.1 wan-encapsulation ppp speed 45000000 clock
internal-clock-51mhz
     !
To configure IP interfaces:
 2 : interface create ip 20net address-netmask 20.1.1.1/16 port et.1.2
 3 : interface create ip 22net address-netmask 22.1.1.1/16 port et.1.1
 4 : interface create ip 100net address-netmask 100.1.1.1/8 port hs.5.1
     !
To configure router R1's area:
 5 : isis add area 49.da01
To enable IS-IS on each interface:
 6 : isis add interface 20net
 7 : isis add interface 22net
 8 : isis add interface 100net
To set IS-IS parameters for each interface:
 9 : isis set interface 20net encap iso priority 10 metric 10 level 1
10 : isis set interface 22net encap iso priority 10 metric 10 level 1
11 : isis set interface 100net encap iso priority 10 metric 10 level 2
To set the IS-IS level of router R1:
12 : isis set level 1-and-2
To start IS-IS on router R1:
13 : isis start
     !
```


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R2 Configuration

The following is the configuration for router R2 in Area 1:

```
R2(config)# sh
Running system configuration:
To configure the IP VLAN, 21net:
 1 : vlan create 21net ip
 2 : vlan add ports et.1.3,et.1.4 to 21net
     !
To configure ports et.1.1 and et.1.2, and VLAN 21net as separate IP
interfaces:
 3 : interface create ip 23net address-netmask 23.1.1.1/16 port et.1.1
 4 : interface create ip 21net address-netmask 21.1.1.1/16 vlan 21netvlan
 5 : interface create ip 20net address-netmask 20.1.1.2/16 port et.1.2
     !
To configure router R2's area:
 6 : isis add area 49.da01
To enable IS-IS on each IP interface:
 7 : isis add interface 23net
 8 : isis add interface 21net
 9 : isis add interface 20net

To set IS-IS parameters for each interface:
10 : isis set interface 23net encap iso priority 10 metric 10 level 1
11 : isis set interface 21netvlan encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R2:
12 : isis set level 1
13 : isis set interface 20net encap iso level 1 priority 10 metric 10
To start IS-IS on router R2:
14 : isis start
     !
```


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R3 Configuration

The following is the configuration for router R3 in Area 1:

```
R3(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 22:48:47
     !
To configure IP interfaces:
 1 : interface create ip 21net address-netmask 21.1.1.2/16 port et.1.3
 2 : interface create ip 24net address-netmask 24.1.1.1/16 port et.1.1
     !
To configure router R3's area:
 3 : isis add area 49.da01
To enable IS-IS on each interface:
 4 : isis add interface 21net
 5 : isis add interface 24net
To set parameters for each interface:
 6 : isis set interface 21net encap iso priority 10 metric 10 level 1
 7 : isis set interface 24net encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R3:
 8 : isis set level 1-and-2
To start IS-IS on router R3:
 9 : isis start
      !
```


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R4 Configuration

The following is the configuration for R4 in Area 1:

```
R4(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 17:50:12
     !
To configure IP interfaces:
 1 : interface create ip 21net address-netmask 21.1.1.3/16 port et.1.4
 2 : interface create ip 25net address-netmask 25.1.1.1/16 port et.1.1
     !
To configure router R4's area:
 3 : isis add area 49.da01
To enables IS-IS on each interface:
 4 : isis add interface 21net
 5 : isis add interface 25net
To set parameters for each interface:
 6 : isis set interface 21net encap iso priority 10 metric 10 level 1
 7 : isis set interface 25net encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R4:
 8 : isis set level 1-and-2
To start IS-IS on router R4:
 9 : isis start
     !
```


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R5 Configuration

The following is the configuration for R5 in Area 2:

```
R5(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 09:31:01
     !
To set WAN encapsulation for port hs.5.1:
 1 : port set hs.5.1 wan-encapsulation ppp speed 45000000 clock
internal-clock-51mhz
     !
To create IP interfaces:
 2 : interface create ip 35net port et.1.8 address-netmask 35.1.1.2/16
 3 : interface create ip 100net address-netmask 100.1.1.2/8 port hs.5.1
 4 : interface create ip 30net address-netmask 30.1.1.1/16 port et.1.2
 5 : interface create ip 105net address-netmask 105.1.1.2/16 port et.1.3
 6 : interface add ip en0 address-netmask 10.50.3.4/16
     !
To set BGP parameters:
 7 : ip-router global set router-id 30.1.1.1
 8 : ip-router global set autonomous-system 64977
     !
 9 : ip add route 100.100.100.100 interface 35net
     !
10 : bgp create peer-group bgpfeed type external autonomous-system 64901
11 : bgp add peer-host 35.1.1.1 group bgpfeed
12 : bgp start
     !
To configure the IS-IS area:
13 : isis add area 49.da02

To enable IS-IS on each interface:
14 : isis add interface 100net
15 : isis add interface 30net
16 : isis add interface 105net
To set parameters for each interface:
17 : isis set interface 100net level 2 encap iso priority 10 metric 10
18 : isis set interface 30net level 2 encap iso priority 10 metric 10
19 : isis set interface 105net level 2 encap iso priority 10 metric 10
To set the IS-IS level of router R5:
20 : isis set level 1-and-2
To start IS-IS on R5:
21 : isis start
     !
To redistribute static routes into IS-IS:
22 : ip-router policy redistribute from-proto static to-proto isis
To redistribute BGP routes into IS-IS:
23 : ip-router policy redistribute from-proto bgp to-proto isis source-as 64901
     !
```


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R6 Configuration

The following is the configuration for R6 in Area 2:

```
R6(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 08:36:43
     !
To configure IP interfaces:
 1 : interface create ip 110net address-netmask 110.1.1.1/8 port et.1.4
 2 : interface create ip 31net address-netmask 31.1.1.1/16 port et.1.3
 3 : interface create ip 30net address-netmask 30.1.1.2/16 port et.1.2
     !
To configure an OSPF interface for the backbone area:
 4 : ospf create area backbone
 5 : ospf add interface 31net to-area backbone
To starts OSPF:
 6 : ospf start
     !
To configure the IS-IS area of router R6:
 7 : isis add area 49.da02

To enable IS-IS on each interface:
 8 : isis add interface 30net
 9 : isis add interface 110net
To set parameters for each interface:
10 : isis set interface 110net level 2 priority 10 metric 10 encap iso
11 : isis set interface 30net encap iso level 2 priority 10 metric 10
To set the IS-IS level of router R6:
12 : isis set level 1-and-2
To start IS-IS on router R6:
13 : isis start
     !
To redistribute IS-IS routes into OSPF:
14 : ip-router policy redistribute from-proto isis to-proto ospf
     !
```


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R7 Configuration

The following is the configuration for R7 in Area 2:

```
R7(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-04 15:18:34
     !
To configure an IP interface:
 1 : interface create ip 31net address-netmask 31.1.1.2/16 port et.1.3
     !
To configure and start OSPF:
 2 : ospf create area backbone
 3 : ospf add interface 31net to-area backbone
 4 : ospf start
     !
```

R8 Configuration

The following is the configuration for R8 in Area 3:

```
R8(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 09:33:34
     !
To configure IP interfaces:
 1 : interface create ip 40net address-netmask 40.1.1.1/16 port et.1.2
 2 : interface create ip 41net address-netmask 41.1.1.1/16 port et.1.1
 3 : interface create ip 105net address-netmask 105.1.1.1/8 port et.1.3
     !
To configure the IS-IS area of R8:
 4 : isis add area 49.da03
To enable IS-IS on each interface:
 5 : isis add interface 40net
 6 : isis add interface 41net
 7 : isis add interface 105net
To set the IS-IS level of router R8:
 8 : isis set level 1-and-2
To set the parameters of each interface:
 9 : isis set interface 40net encap iso level 1 priority 10 metric 10
10 : isis set interface 41net encap iso level 1 priority 10 metric 10
11 : isis set interface 105net encap iso level 2 priority 10 metric 10
To start IS-IS on router R8:
12 : isis start
     !
```


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R9 Configuration

The following is the configuration for R9 in Area 3:

```
R9(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 11:32:26
     !
To create IP interfaces:
 1 : interface create ip 40net address-netmask 40.1.1.2/16 port et.1.2
 2 : interface create ip 42net address-netmask 42.1.1.1/16 port et.1.1
     !
To configure the IS-IS area of router R9:
 3 : isis add area 49.da03
To enable IS-IS on each interface:
 4 : isis add interface 40net
 5 : isis add interface 42net
To set the parameters for each interface:
 6 : isis set interface 40net encap iso level 1 priority 10 metric 10
 7 : isis set interface 42net encap iso level 1 priority 10 metric 10
To set the IS-IS level of router R9:
 8 : isis set level 1
To start ISIS on R9:
 9 : isis start
     !
```


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C10 Configuration

The following is the configuration for the C10 Cisco router in Area 4:

```
Router#sh ru
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname Router
!
!
clns routing
!
interface Serial0/0
 ip address 52.1.1.1 255.255.0.0
 ip router isis 49.0004
 encapsulation ppp
 no keepalive
 no peer default ip address
 isis circuit-type level-1
 isis priority 10 level-1
!
interface Serial0/1
 no ip address
 shutdown
!
interface Serial0/2
 no ip address
 shutdown
!
interface Serial0/3
 no ip address
 shutdown
!
interface Ethernet1/0
 ip address 51.1.1.1 255.255.0.0
 ip router isis 49.0004
 isis circuit-type level-1
 isis priority 10 level-1
!
```


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C10 Configuration (continued)

```
interface Ethernet1/1
 ip address 110.1.1.2 255.0.0.0
 ip router isis 49.0004
 isis circuit-type level-2-only
 isis priority 10 level-1
!
interface Ethernet1/2
 ip address 111.1.1.2 255.0.0.0
 ip router isis 49.0004
 isis circuit-type level-2-only
 isis priority 10 level-1
!
interface Ethernet1/3
 no ip address
 shutdown
!
interface Ethernet1/4
 no ip address
 shutdown
!
interface Ethernet1/5
 no ip address
 shutdown
!
router isis 49.0004
 net 49.0004.0200.3301.0101.00
!
router bgp 5
 neighbor 198.92.70.24 remote-as 10
 neighbor 198.92.70.24 route-map in5 in
!
no ip classless
!
!
line con 0
line aux 0
line vty 0 4
 login
!
end
```


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R11 Configuration

The following is the configuration for R11 in Area 4:

```
R11(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 10:19:40
     !
To configure the WAN port se.4.3:
 1 : port set se.4.3 wan-encapsulation ppp speed 45000000
     !
To configure IP interfaces:
 2 : interface create ip 52net address-netmask 52.1.1.2/16 port se.4.3
 3 : interface create ip 51net address-netmask 51.1.1.2/16 port et.1.2
 4 : interface add ip en0 address-netmask 10.50.3.11/16
     !
To configure the IS-IS area of router R11:
 5 : isis add area 49.0004
To enable IS-IS on each interface:
 6 : isis add interface 51net
 7 : isis add interface 52net
To set the IS-IS level of router R11:
 8 : isis set level 1
To set the parameters for each interface:
 9 : isis set interface 51net level 1 encap iso priority 10 metric 10
10 : isis set interface 52net level 1 encap iso priority 10 metric 10
To start IS-IS on the router:
11 : isis start
     !
```


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16 BGP CONFIGURATION GUIDE

The Border Gateway Protocol (BGP) is an exterior gateway protocol that allows IP routers to exchange network reachability information. BGP became an internet standard in 1989 (RFC 1105) and the current version, BGP-4, was published in 1994 (RFC 1771). BGP is typically run between Internet Service Providers. It is also frequently used by multi-homed ISP customers, as well as in large commercial networks.

Autonomous systems that wish to connect their networks together must agree on a method of exchanging routing information. Interior gateway protocols such as RIP and OSPF may be inadequate for this task since they were not designed to handle multi-AS, policy, and security issues. Similarly, using static routes may not be the best choice for exchanging AS-AS routing information because there may be a large number of routes, or the routes may change often.

Note This chapter uses the term *Autonomous System* (AS) throughout. An AS is defined as a set of routers under a central technical administration that has a coherent interior routing plan and accurately portrays to other ASs what routing destinations are reachable by way of it.

In an environment where using static routes is not feasible, BGP is often the best choice for an AS-AS routing protocol. BGP prevents the introduction of routing loops created by multi-homed and meshed AS topologies. BGP also provides the ability to create and enforce policies at the AS level, such as selectively determining which AS routes are to be accepted or what routes are to be advertised to BGP peers.

16.1 THE RS BGP IMPLEMENTATION

The RS routing protocol implementation, ROSRD, is a modular software program that consists of core services, a routing database, and protocol modules that support multiple routing protocols (RIP versions 1 and 2, OSPF version 2, BGP version 4, and integrated IS-IS).

BGP can be configured with the RS command line interface (CLI). Since the RS IP routing code is compatible with GateD 4.0.3 code, BGP can also be configured using a GateD configuration file (**`gated.conf`**). Additionally, even if the RS is configured using the CLI, the **`gated.conf`** equivalent can be displayed by entering the **`ip-router show configuration-file`** command at the RS Enable prompt. VLANs, interfaces, ACLs, and many other RS configurable entities and functionality can only be configured using the RS CLI. Therefore, a **`gated.conf`** file is dependent upon some RS CLI configuration.

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16.2 BASIC BGP TASKS

This section describes the basic tasks necessary to configure BGP on the RS. Due to the abstract nature of BGP, many BGP designs can be extremely complex. For any one BGP design challenge, there may only be one solution out of many that is relevant to common practice.

When designing a BGP configuration, it may be prudent to refer to information in RFCs, Internet drafts, and books about BGP. Some BGP designs may also require the aid of an experienced BGP network consultant.

Basic BGP configuration involves the following tasks:

- Setting the autonomous system number
- Setting the router ID
- Creating a BGP peer group
- Adding a BGP peer host
- Starting BGP
- Using AS path regular expressions
- Using AS path prepend
- Creating BGP confederations
- Creating community lists
- Using route maps
- Using BGP accounting

16.2.1 Setting the Autonomous System Number

An autonomous system number identifies your autonomous system to other routers. To set the autonomous system number for the RS, enter the following command in Configure mode.

Set the router's autonomous system number.	**ip-router global set autonomous-system** <*num1*> **loops** <*num2*>

The **autonomous-system** <*num1*> parameter sets the AS number for the router. Specify a number from 1 to 65535. The **loops** <*num2*> parameter controls the number of times the AS may appear in the as-path. The default is 1.

16.2.2 Setting the Router ID

The router ID uniquely identifies the RS. To set the router ID to be used by BGP, enter the following command in Configure mode.

Set the router ID.	**ip-router global set router-id** <*hostname-or-IPaddr*>

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If you do not explicitly specify the router ID, then an ID is chosen implicitly by the RS. A secondary address on the loopback interface (the primary address being 127.0.0.1) is the most preferred candidate for selection as the router ID. If there are no secondary addresses on the loopback interface, then the default router ID is set to the address of the first interface that is in the up state that the RS encounters (except the interface en0, which is the Control Module's interface). The address of a non point-to-point interface is preferred over the local address of a point-to-point interface. If the router ID is implicitly chosen to be the address of a non-loopback interface, and if that interface were to go down, then the router ID is changed. When the router ID changes, an OSPF router has to flush all its LSAs from the routing domain.

If you explicitly specify a router ID, then it would not change, even if all interfaces were to go down.

16.2.3 Configuring a BGP Peer Group

A BGP peer group is a group of neighbor routers that have the same update policies. To configure a BGP peer group, enter the following command in Configure mode:

Configure a BGP peer group.	**bgp create peer-group** <*number-or-string*> **type external|routing [autonomous-system** <*number*>**] [proto any|rip|ospf|static] [interface** <*interface-name-or-ipaddr*> **|all]**

where:

peer-group <*number-or-string*>
Is a group ID, which can be a number or a character string.

type Specifies the type of BGP group you are adding. You can specify one of the following:

- **external** In the classic external BGP group, full policy checking is applied to all incoming and outgoing advertisements. The external neighbors must be directly reachable through one of the machine's local interfaces.
- **routing** An internal group which uses the routes of an interior protocol to resolve forwarding addresses. Type Routing groups will determine the immediate next hops for routes by using the next hop received with a route from a peer as a forwarding address, and using this to look up an immediate next hop in an IGP's routes. Such groups support distant peers, but need to be informed of the IGP whose routes they are using to determine immediate next hops. This implementation comes closest to the IBGP implementation of other router vendors.

autonomous-system <*number*>
Specifies the autonomous system of the peer group. Specify a number from 1 to 65535.

proto Specifies the interior protocol to be used to resolve BGP next hops.

interface <*name-or-IPaddr*> | **all**
Interfaces whose routes are carried via the IGP for which third-party next hops may be used instead. Use only for type Routing group. Specify the interface or **all** for all interfaces.

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16.2.4 Adding a BGP Peer

To add BGP peers to BGP peer groups, enter the following command in Configure mode.

Add a host to a BGP peer group.	**bgp add peer-host** <*ipaddr*> **group** <*number-or-string*>

You can specify either a peer group identifier or a peer host IP address when creating an export destination for BGP routes (with the **ip-router policy create bgp-export-destination** command), a source for exporting BGP routes into other protocols (with the **ip-router policy create bgp-export-source** command), or a source for importing BGP routes (with the **ip-router policy create bgp-import-source** command).

16.2.5 Starting BGP

BGP is disabled by default. To start BGP, enter the following command in Configure mode.

Start BGP.	**bgp start**

16.2.6 Using AS-Path Regular Expressions

AS path regular expressions are used as one of the parameters for determining which routes are accepted and which routes are advertised. An AS path regular expression is a regular expression where the alphabet is the set of AS numbers from 1 through 65535.

The following wildcards and operators can be used to build a regular expression:

" "	(quotation marks)	Encloses an AS path regular expression
()	(parentheses)	Used to group expressions within the AS path regular expression
.	(period)	Matches any AS number
*****	(asterisk	Matches zero or more repetitions of the preceding expression
+	(plus sign)	Matches one or more repetitions of the preceding expression
?	(question mark)	Matches zero or one repetition of the prceding expression
	(space)	And
|	(vertical line)	Or

A set of AS numbers is delimited by the **[]** (square bracket) symbols. The set can be a list of AS numbers separated by a space or a range of AS numbers separated by a **-** (dash). A ^ (circumflex) prepended to a list of AS numbers means that valid members are those AS numbers that are *not* in the list. Note that a null or empty string is not an instance in the alphabet, therefore the set [^700] does not match an empty string.

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For example:

"."	Matches any single AS number as the AS path.
"700.*"	Matches all AS paths coming from an AS that starts with 700.
".* [^700 800]"	Matches all paths that do not end with AS numbers 700 and 800 and have at least one AS.
"[1-64999]*"	Matches a path that has only valid exterior AS numbers.
"700 800 [^100]"	Matches AS numbers 700 and 800 and any other AS number except 100.
"700 800 [^100]?"	Matches AS numbers 700 and 800 and any other AS number except 100, or no additional AS numbers in the path.
"700|800"	Matches either 700 or 800 with no additional AS numbers in the path.

AS Path Regular Expression Examples

In the following example, routes from AS 61972 and 61678 that have traversed AS 3561 are imported. The first command creates an AS path regular expression with the identifer 'mciAspath' to match AS paths that include AS 3561. The next two commands specify the AS path regular expression identifier to match routes imported from AS 61972 and 61678.

```
ip-router policy create aspath-regular-expression mciAspath  ".* 3561 .*"
ip-router policy create bgp-import-source bisrc61972 aspath-regular-expression
    mciAspath autonomous-system 61972 origin any
ip-router policy create bgp-import-source bisrc61678 aspath-regular-expression
     mciAspath autonomous-system 61678 origin any
ip-router policy import source bisrc61972 network all preference 160
ip-router policy import source bisrc61678 network all preference 170
```

To import all routes (.* matches all AS paths) with the default preference:

```
ip-router policy create aspath-regular-expression allAspaths ".*"
ip-router policy create bgp-import-source allOthers aspath-regular-expression
     allAspaths origin any sequence-number 20
ip-router policy import source allOthers network all
```


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To export all active routes from 284 or 813 or 814 or 815 or 816 or 3369 or 3561 to autonomous system 64800.

```
ip-router policy create aspath-regular-expression someAspath
     ".*(284|813|814|815|816|3369|3561) .*"
ip-router policy create bgp-export-destination to-64800 autonomous-system 64800
ip-router policy create aspath-export-source allRoutes aspath-regular-expression
     someAspath origin any protocol all
ip-router policy export destination to-64800 source allRoutes network all
```

16.2.7 Using the AS Path Prepend Feature

When BGP compares two advertisements of the same prefix that have differing AS paths, the default action is to prefer the path with the lowest number of transit AS hops; in other words, the preference is for the shorter AS path length. The AS path prepend feature is a way to manipulate AS path attributes to influence downstream route selection. AS path prepend involves inserting the originating AS into the beginning of the AS prior to announcing the route to the exterior neighbor.

Lengthening the AS path makes the path less desirable than would otherwise be the case. However, this method of influencing downstream path selection is feasible only when comparing prefixes of the same length because an instance of a more specific prefix always is preferable.

On the RS, the number of instances of an AS that are put in the route advertisement is controlled by the **`as-count`** option of the **`bgp set peer-host`** command.

The following is an example:

```
#
# insert two instances of the AS when advertising the route to this peer
#
bgp set peer-host 194.178.244.33 group nlnet as-count 2
#
# insert three instances of the AS when advertising the route to this
# peer
#
bgp set peer-host 194.109.86.5 group webnet as-count 3
```

Notes on Using the AS Path Prepend Feature

Use the **`as-count`** option for external peer-hosts only.

If the **`as-count`** option is entered for an active BGP session, routes will ***not*** be resent to reflect the new setting. To have routes reflect the new setting, you must restart the peer session. To do this:

1. Enter Configure mode.
2. Negate the command that adds the peer-host to the peer-group. (If this causes the number of peer-hosts in the peer-group to drop to zero, then you must also negate the command that creates the peer group.)

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3. Exit Configure mode.
4. Re-enter Configure mode.
5. Add the peer-host back to the peer-group.

If the **`as-count`** option is part of the startup configuration, the above steps are unnecessary.

16.2.8 Creating BGP Confederations

In a BGP autonomous system, each iBGP router has to peer with all other iBGP routers over a direct link. This is known as a "routing mesh." In a large AS, the number of peers and the number links between peers can be significant.

Creating a BGP confederation reduces the number of links between BGP peers by consolidating small autonomous systems into a larger AS. To BGP routers that are not part of the confederation, sub-AS's appear as a single AS with a single, externally-visible AS number. Each BGP confederation router uses its internal, sub-AS number to communicate with peers that are members of its confederation. Therefore, a router in a BGP confederation must be configured with both the AS number of the confederation (the externally-visible AS number) as well as the number of its sub-AS.

In Figure 16-1, a BGP confederation with the AS number 64801 consists of sub-AS's 100, 101, 102, and 103. BGP routers outside the confederation see only AS 64801; they cannot see the sub-AS's. For example, R2 resides in AS 1000. When R2 communicates with R1, it sees R1 as part of AS 64801; R2 does not know that R1 is a member of AS 102.

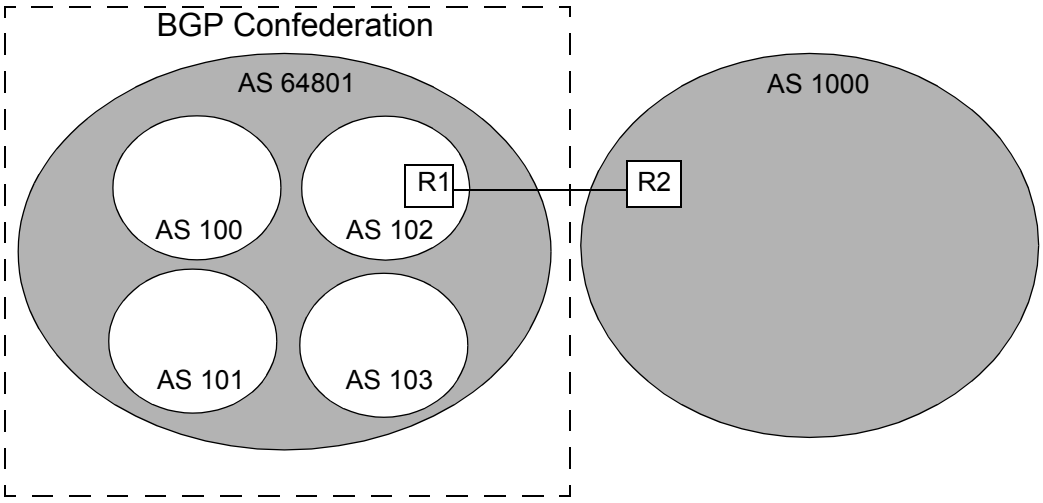

Figure 16-1 BGP confederation

BGP confederations assume that a single IGP runs across the entire confederation. BGP sessions between routers that are in the same confederation but in different sub-AS's are also known as EIBGP sessions. EIBGP sessions are similar to EBGP sessions with the following differences:

- Local preference attributes in learned routes are allowed to traverse sub-AS's instead of being ignored. For example, in Figure 16-1, R1 establishes a local preference value for a route advertised by R2. AS 102 must be allowed to advertise the local preference value to the other sub-AS's in the confederation.
- The next hop attribute is set by the first-hop router in the confederation and is then allowed to traverse sub-AS's without being changed.

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- To prevent looping of routing announcements within the confederation, the AS-path attribute uses two new path segment types: as-confed-set and as-confed-sequence are similar to the as-set and as-sequence attributes, except they are only used *within* a confederation.

The confederation structure is hidden whenever an EBGP session takes place between a router in a sub-AS and a router outside the confederation. In Figure 16-1, when R1 advertises a route to R2, R1 strips any as-confed-sequence and as-confed-set path segments from the as-path attribute and adds AS 64801 to the as-path attribute. When R1 learns a route from R2 and advertises the route via EIBGP to a router in another member AS, R1 adds the as-confed-sequence path segment to the as-path attribute and includes its sub-AS number (102) in the new path segment.

16.2.9 Creating Community Lists

A community is a group of destinations that share a common property. A community is defined by the administrator of the autonomous system and can be used as a way of filtering BGP routes.

To create and define community lists on an RS, enter the following commands in Configure mode:

Create a community list.	**ip-router policy create community-list** <*identifier*> <*community-string*>
Add communities to a community list.	**ip-router policy add community-list** <*identifier*> <*community-string*>

The <*community-string*> is in the form "<*AS-identifier*>:<*community-identifier*>." The **bgp show routes** command shows communities associated with a BGP route.

Community lists can be specified in route maps. Communities in a BGP route can be compared to the community list. The communities in the route can either be a superset of the specified communities or they can exactly match the specified communities. Route map actions can include removing the community attribute from a route, setting the value of the community attribute, adding communities to the route, or deleting communities from the route. With route maps, you can also specify keywords for certain well-known communities:

Table 16-1 Keywords for well-known communities

Keyword	Community	Description
no_export	65535:65281	Do not advertise to EBGP peers.
no_advertise	65535:65282	Do not advertise to any peer.
no_export_subconfed	65535:65283	Do not advertise to EBGP peers, including peers inside a BGP confederation.

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16.2.10 Using Route Maps

A route map defines conditions and actions to be taken for:

- importing routes from BGP peer groups or hosts
- exporting routes to BGP peer groups or hosts
- redistributing routes from any routing protocol into BGP
- redistributing routes from BGP into any other routing protocol (only conditions are considered, actions have no effect)

A route map consists of one or more *conditions* that define BGP information and the *action* to be taken when the condition is met. Each condition tells the RS to either permit or deny route that matches the criteria specified in the route map. To be imported, exported, or redistributed, a route needs to meet the conditions of a configured route map. Note that a route can meet the conditions of a route map where the keyword **deny** is explicitly specified; in this case, the route will *not* be imported, exported, or redistributed.

Note For route maps to take effect, the RS must be selecting BGP for the route. Make sure that BGP preference is set lower than the preference of other protocols on the RS.

To create a route map, enter the following command in Configure mode:

Create a route map.	**route-map** <*number-or-string*> **permit** <*sequence-number*> <*match-criteria*> <*action*> **route-map** <*number-or-string*> **deny** <*sequence-number*> <*match-criteria*>

In the following example, when the prefix of a route matches the network address 15.4.0.0, the route is redistributed with a next hop of 12.10.4.13.

```
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-next-hop 12.10.4.13
```

You can specify the configured route map for an export, import, or redistribution policy (with the **ip-router policy export**, **ip-router policy import**, or **ip-router policy redistribute** command). You can also specify the route map when exporting routes to or importing routes from a peer group or a peer host; this is done with the

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route-map-in (import) or **route-map-out** (export) option of the **bgp set peer-group** or **bgp set peer-host** commands. For example, the following commands apply the route map with the identifier '1' for routes that are exported to the peer group 'pub1':

```
bgp create peer-group pub1 type external autonomous-system 3937
bgp add peer-host 14.2.3.23 group pub1
bgp set peer-group pub1 route-map-out 1
```

For EBGP, route maps can be applied to *either* a peer group or a peer host. For IBGP, the **route-map-out** option *cannot* be used to set a value for a peer host. If you need to control the export of routes to specific IBGP peers, create a peer group for each peer and define a group-specific policy. This restriction does not apply to the **route-map-in** option.

Defining Match Criteria in Route Map Conditions

Match criteria in a route map condition describes the BGP route information that is to be filtered. The following match criteria can be specified:

- Route prefix, as specified by a previously-defined route filter or network specification
- Source protocol of the route
- Next hop for the route, as specified by a previously-defined route filter
- BGP local preference value
- BGP Multi Exit Descriminator (MED) value
- BGP origin attribute
- aspath regular expression
- Communities in route are either part of or exactly the same as previously-defined community list

When you create a route map, you specify a route map *identifier*. You can create multiple conditions with the same identifier. The sequence number in the route map definition specifies the order of a particular condition in relation to other conditions with the same route map identifier. The condition with the lowest sequence number is applied first. If the specified condition is not met, the condition with the next-lowest sequence number is applied. A route is checked against conditions in this manner until a set of route map conditions is met or there are no more conditions. If a route does not meet any configured route map conditions, the route is not imported, exported, or redistributed.

If a route matches a condition, it is imported, exported, or redistributed, or not, based on the **permit** or **deny** keyword. All subsequent conditions are ignored. Consequently, conditions that are more specific should always have lower sequence numbers than conditions that are less specific. In the following example, when the prefix of a route matches the network address 15.4.0.0, the route is redistributed with a next hop of 12.10.4.13. But when the prefix of a route matches the network address 13.0.0.0/16, the route is not imported, exported, or distributed.

```
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-next-hop 12.10.4.13
route-map 1 deny 2 match-prefix network 15.0.0.0/8
```


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Defining Actions in Route Map Conditions

When a route matches a condition configured with the **permit** keyword, the specified action is taken. The following actions can be specified:

- Set the next hop for the route
- Set the local preference for the route
- Set the MED for the route
- Set the original for the route
- Prepend the AS number to the AS path for the route
- Remove or add communities to the route
- Set the preference for the route
- Specify the traffic bucket number for the route (see Section 16.3.11, *"BGP Accounting Examples,"* for more information)

16.2.11 Using BGP Accounting

BGP accounting allows you to differentiate and tally IP traffic by assigning traffic indexes based on route map specifications to an input interface. Using BGP accounting, you can collect statistics (and apply billing) according to route-specific traffic. For example, domestic, international, terrestrial, satellite, and other traffic can be identified and accounted for on a per-customer basis.

You can also choose to count route-specific traffic according to Differentiated Services Code Point (DSCP) values (previously known as Type of Service values) in the packets. This allows you to collect and bill on a service level for each customer.

Enabling BGP Accounting

In the following example, BGP packets with the community value “11:11” are forwarded from router R1 to router R2. On router R2, a traffic index is set up to keep the counts of these packets.

On the router R1, create a community list for the community value “11:11.” For example, the following commands create a route-map for the community value “11:11”:

```
route-map 1 permit 1 set-community-list “11:11”
bgp set peer-group r2 route-map-out 1 out-sequence 1
```

On the router R2, do the following:

1. Create a community list to match the community value “11:11” and define a route-map that matches the community with a specific traffic index. For example, the following commands create a community list with the community value “11:11” and define a route map to match the community list with the traffic index ’1’:

```
ip-router policy create community-list list1 "11:11"
route-map 1 permit 1 match-community-list list1 set-traffic-index 1
```


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2. Enable the route-map on incoming traffic from router R1. For example, the following command applies the route-map ’1’ to routes imported from the peer group ’r1’:

```
bgp set peer-group r1 route-map-in 1 in-sequence 1
```

3. Add the interface name to the BGP accounting table. For example, the following command enables BGP accounting on the interface ’customerA’:

```
ip enable bgp-actg-on customerA
```

4. Start BGP accounting. For example, to start collecting statistics for the service levels (DSCP values) of specific traffic routes:

```
ip bgp-accounting start dscp-accounting
```

To start collecting BGP traffic statistics for specific traffic routes:

```
ip bgp-accounting start accounting
```

Refer to Section 16.3.11, *"BGP Accounting Examples,"* to see detailed example configurations.

Displaying BGP Accounting Information

Use the **bgp-actg** option with the **ip show interfaces** command to display BGP accounting information on a per-interface basis. For example:

```
rs# ip show interfaces int1 bgp-actg

Interface:int1
Bucket Packets       Bytes
0      0             0
1      111           14430
```


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The example output shown above displays the number of packets and bytes sent at the interface 'int1'. The user has sent 111 packets of size 130 bytes that fell into bucket 1 (traffic index 1). For example, a ping request (with a data size of 84 bytes) was sent 111 times.

Use the **`ip clear bgp-actg`** command to clear BGP accounting statistics. For example:

```
rs# ip clear bgp-actg

rs# ip show interfaces int1 bgp-actg

Interface:int1
Bucket Packets       Bytes
0      0             0
1      0             0
```

If you need to see which traffic index is assigned to a route, run the following Diagnostic mode command:

```
rs# diag
rs? ip find route 14.1.0.0
     route to: 14.1.0.0
         mask: (255) ffff ffff
    interface: toRTR2
      gateway: 12.1.1.2
  aspath info: Next Hop - 0, Origin -  0
traffic index: 1
        flags: <UP,GATEWAY>
recvpipe  sendpipe  ssthresh  rtt,msec    rttvar  hopcount      mtu
   16384     16384         0         0     e
```

16.3 BGP CONFIGURATION EXAMPLES

This section presents sample configurations illustrating BGP features. The following features are demonstrated:

- BGP peering
- Internal BGP (IBGP)
- External BGP (EBGP) multihop
- BGP community attribute
- BGP local preference (local_pref) attribute
- BGP Multi-Exit Discriminator (MED) attribute
- EBGP aggregation
- Route reflection
- BGP confederation
- Route map

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- BGP accounting

16.3.1 BGP Peering Session Example

The router process used for a specific BGP peering session is known as a *BGP speaker*. A single router can have several BGP speakers. Successful BGP peering depends on the establishment of a neighbor relationship between BGP speakers. The first step in creating a BGP neighbor relationship is the establishment of a TCP connection (using TCP port 179) between peers.

A BGP Open message can then be sent between peers across the TCP connection to establish various BGP variables (BGP Version, AS number (ASN), hold time, BGP identifier, and optional parameters). Upon successful completion of the BGP Open negotiations, BGP Update messages containing the BGP routing table can be sent between peers.

BGP does not require a periodic refresh of the entire BGP routing table between peers. Only incremental routing changes are exchanged. Therefore, each BGP speaker is required to retain the entire BGP routing table of their peer for the duration of the peer's connection.

Note To request route database refreshes from peer-hosts, first add **`bgp set peer-host/peer-group route refresh`** to the active configuration. Then, use the **`bgp clear peer-host soft-inbound`** command. The **`soft-inbound`** option causes the peer-host to re-send it routing information without breaking and then reestablishing the connection to the peer-host.

BGP "keepalive" messages are sent between peers periodically to ensure that the peers stay connected. If one of the routers encounters a fatal error condition, a BGP notification message is sent to its BGP peer, and the TCP connection is closed.

Figure 16-2 illustrates a sample BGP peering session:

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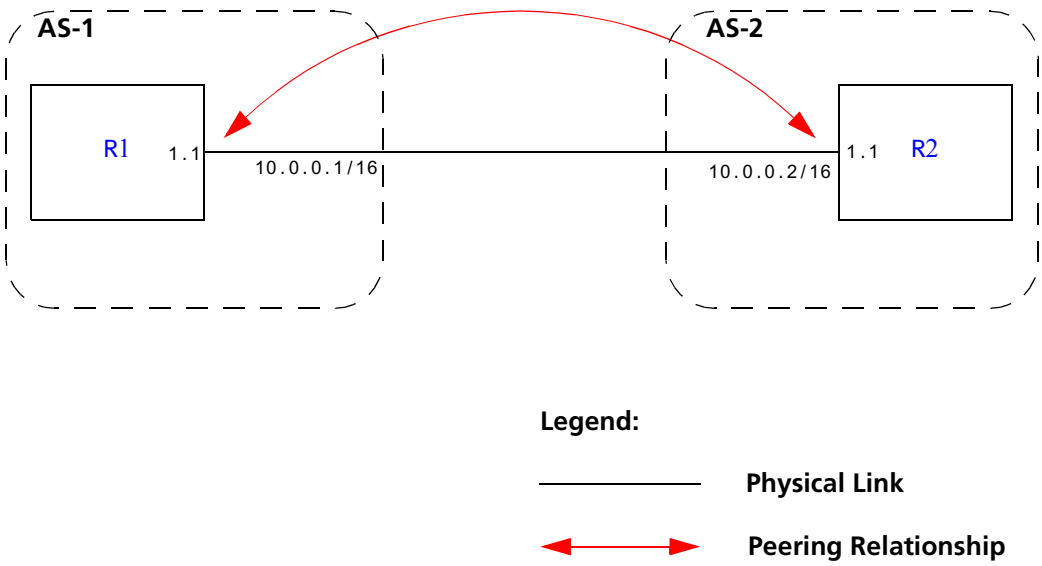

Figure 16-2 Sample BGP peering session

The CLI configuration for router R1 is as follows:

```
interface create ip et.1.1 address-netmask 10.0.0.1/16 port et.1.1
#
# Set the AS of the router
#
ip-router global set autonomous-system 1
#
# Set the router ID
#
ip-router global set router-id 10.0.0.1
#
# Create EBGP peer group pg1w2 for peering with AS 2
#
bgp create peer-group pg1w2 type external autonomous-system 2
#
# Add peer host 10.0.0.2 to group pg1w2
#
bgp add peer-host 10.0.0.2 group pg1w2
bgp start
```


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The **gated.conf** file for router R1 is as follows:

```
autonomoussystem 1 ;
routerid 10.0.0.1 ;
bgp yes {
               group type external peeras 2
               {
                              peer 10.0.0.2
                                                ;
                };
};
```

The CLI configuration for router R2 is as follows:

```
interface create ip et.1.1 address-netmask 10.0.0.2/16 port et.1.1
ip-router global set autonomous-system 2
ip-router global set router-id 10.0.0.2
bgp create peer-group pg2w1 type external autonomous-system 1
bgp add peer-host 10.0.0.1 group pg2w1
bgp start
```

The **gated.conf** file for router R2 is as follows:

```
autonomoussystem 2 ;
routerid 10.0.0.2 ;
bgp yes {
               group type external peeras 1
               {
                              peer 10.0.0.1
                                                ;
                };
};
```

16.3.2 IBGP Configuration Example

Connections between BGP speakers within the same AS are referred to as internal links. A peer in the same AS is an internal peer. Internal BGP is commonly abbreviated IBGP; external BGP is EBGP.

An AS that has two or more EBGP peers is referred to as a multihomed AS. A multihomed AS can “transit” traffic between two ASs by advertising to one AS routes that it learned from the other AS. To successfully provide transit services, all EBGP speakers in the transit AS must have a consistent view of all of the routes reachable through their AS.

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Multihomed transit ASs can use IBGP between EBGP-speaking routers in the AS to synchronize their routing tables. IBGP requires a full-mesh configuration; all EBGP speaking routers must have an IBGP peering session with every other EBGP speaking router in the AS.

An IGP, like OSPF, could possibly be used instead of IBGP to exchange routing information between EBGP speakers within an AS. However, injecting full Internet routes (50,000+ routes) into an IGP puts an expensive burden on the IGP routers. Additionally, IGPs cannot communicate all of the BGP attributes for a given route. It is, therefore, recommended that an IGP not be used to propagate full Internet routes between EBGP speakers. IBGP should be used instead.

IBGP Routing Group Example

An IBGP routing group uses the routes of an interior protocol to resolve forwarding addresses. An IBGP routing group will determine the immediate next hops for routes by using the next hop received with a route from a peer as a forwarding address, and using this to look up an immediate next hop in an IGP's routes. Such groups support distant peers, but need to be informed of the IGP whose routes they are using to determine immediate next hops. This implementation comes closest to the IBGP implementation of other router vendors.

You should use the IBGP routing group as the mechanism to configure the RS for IBGP. If the peers are directly connected, then IBGP using group-type Internal can also be used. Note that for running IBGP using group-type routing you must run an IGP such as OSPF to resolve the next hops that come with external routes. You could also use protocol **any** so that all protocols are eligible to resolve the BGP forwarding address.

Figure 16-3 shows a sample BGP configuration that uses the routing group type.

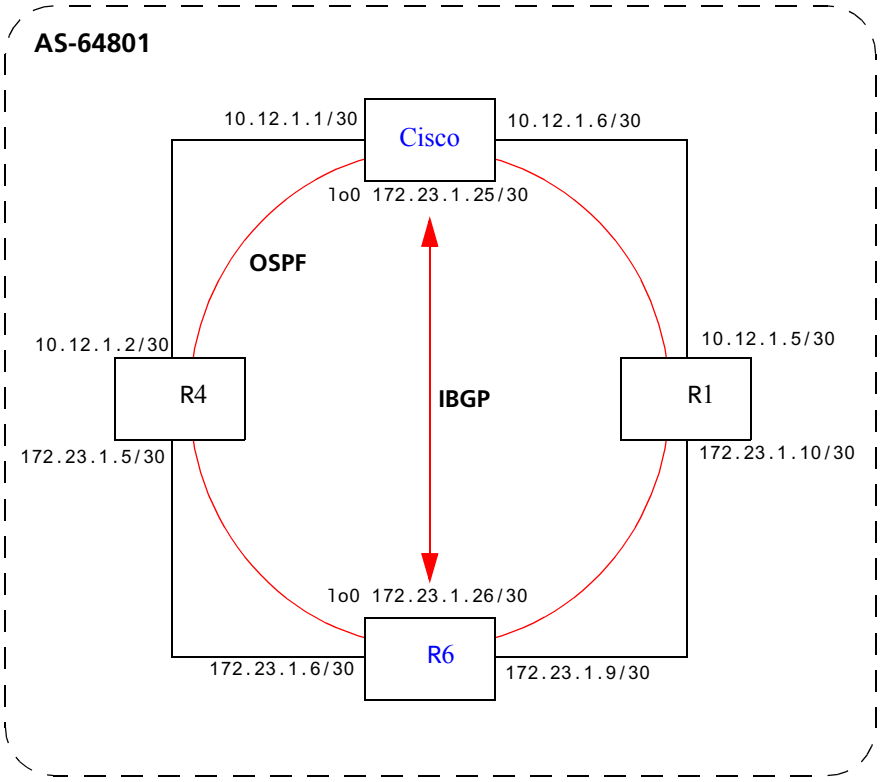

Figure 16-3 Sample IBGP configuration (routing group type)

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In this example, OSPF is configured as the IGP in the autonomous system. The following lines in the router R6 configuration file configure OSPF:

```
#
# Create a secondary address for the loopback interface
#
interface add ip lo0 address-netmask 172.23.1.26/30
ospf create area backbone
ospf add interface to-R4 to-area backbone
ospf add interface to-R1 to-area backbone
#
# This line is necessary because we want CISCO to peer with our loopback
# address.This will make sure that the loopback address gets announced
# into OSPF domain
#
ospf add stub-host 172.23.1.26 to-area backbone cost 1
ospf set interface to-R4 priority 2
ospf set interface to-R1 priority 2
ospf set interface to-R4 cost 2
ospf start
```

The following lines in the Cisco router configure OSPF:

```
The following lines on the CISCO 4500 configures it for OSPF.
router ospf 1
 network 10.12.1.1 0.0.0.0 area 0
 network 10.12.1.6 0.0.0.0 area 0
 network 172.23.1.14 0.0.0.0 area 0
```

The following lines in the R6 set up peering with the Cisco router using the routing group type.

```
# Create a internal routing group.
bgp create peer-group ibgp1 type routing autonomous-system 64801 proto any
interface all
# Add CISCO to the above group
bgp add peer-host 172.23.1.25 group ibgp1
# Set our local address. This line is necessary because we want CISCO to
# peer with our loopback
bgp set peer-group ibgp1 local-address 172.23.1.26
# Start BGP
bgp start
```


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The following lines on the Cisco router set up IBGP peering with router R6.

```
router bgp 64801
!
! Disable synchronization between BGP and IGP
!
 no synchronization
neighbor 172.23.1.26 remote-as 64801
!
! Allow internal BGP sessions to use any operational interface for TCP
! connections
!
 neighbor 172.23.1.26 update-source Loopback0
```

16.3.3 EBGP Multihop Configuration Example

EBGP Multihop refers to a configuration where external BGP neighbors are not connected to the same subnet. Such neighbors are logically, but not physically connected. For example, BGP can be run between external neighbors across non-BGP routers. Some additional configuration is required to indicate that the external peers are not physically attached.

This sample configuration shows External BGP peers, R1 and R4, which are not connected to the same subnet.

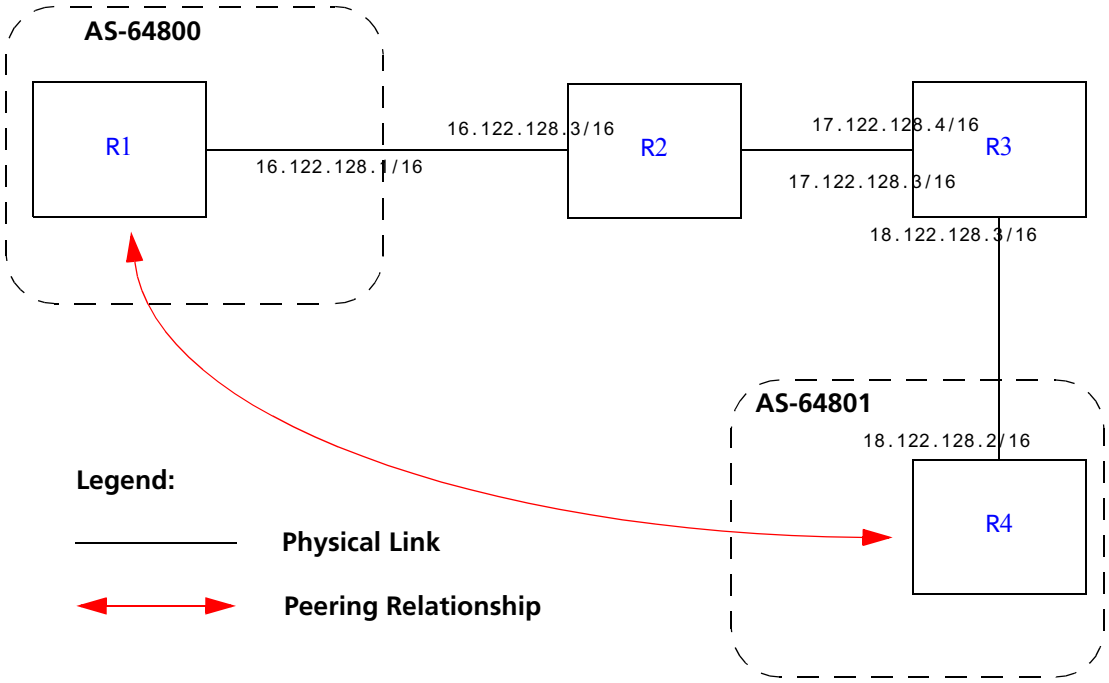

Figure 16-4 Sample EBGP configuration (multihop)

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The CLI configuration for router R1 is as follows:

```
bgp create peer-group ebgp_multihop autonomous-system 64801 type external
bgp add peer-host 18.122.128.2 group ebgp_multihop
!
! Specify the multihop option, which indicates EBGP multihop.
!
bgp set peer-host 18.122.128.2 group ebgp_multihop multihop
```

The **`gated.conf`** file for router R1 is as follows:

```
autonomoussystem 64800 ;

routerid 0.0.0.1 ;

bgp yes {
         traceoptions state ;

         group type external peeras 64801
         {
                 peer 18.122.128.2
                         gateway 16.122.128.3
                         ;
         };
};

static {
         18.122.0.0 masklen 16
                 gateway 16.122.128.3
                 ;
};
```

The CLI configuration for router R2 is as follows:

```
interface create ip to-R1 address-netmask 16.122.128.3/16 port et.1.1
interface create ip to-R3 address-netmask 17.122.128.3/16 port et.1.2
#
# Static route needed to reach 18.122.0.0/16
#
ip add route 18.122.0.0/16 gateway 17.122.128.4
```


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The **gated.conf** file for router R2 is as follows:

```
static {
        18.122.0.0 masklen 16
                gateway 17.122.128.4
                ;
};
```

The CLI configuration for router R3 is as follows:

```
interface create ip to-R2 address-netmask 17.122.128.4/16 port et.4.2
interface create ip to-R4 address-netmask 18.122.128.4/16 port et.4.4
ip add route 16.122.0.0/16 gateway 17.122.128.3
```

The **gated.conf** file for router R3 is as follows:

```
static {
        16.122.0.0 masklen 16
                gateway 17.122.128.3
                ;
};
```

The CLI configuration for router R4 is as follows:

```
bgp create peer-group ebgp_multihop autonomous-system 64801 type external
bgp add peer-host 18.122.128.2 group ebgp_multihop
!
! Specify the multihop option, which indicates EBGP multihop.
!
bgp set peer-host 18.122.128.2 group ebgp_multihop multihop
```


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The **gated.conf** file for router R4 is as follows:

```
autonomoussystem 64800 ;

routerid 0.0.0.1 ;

bgp yes {
         traceoptions state ;

         group type external peeras 64801
         {
                 peer 18.122.128.2
                         gateway 16.122.128.3
```

16.3.4 Community Attribute Example

The following configuration illustrates the BGP community attribute. Community is specified as one of the parameters in the **optional attributes list** option of the **ip-router policy create** command.

Figure 16-5 shows a BGP configuration where the specific community attribute is used. Figure 16-6 shows a BGP configuration where the well-known community attribute is used.

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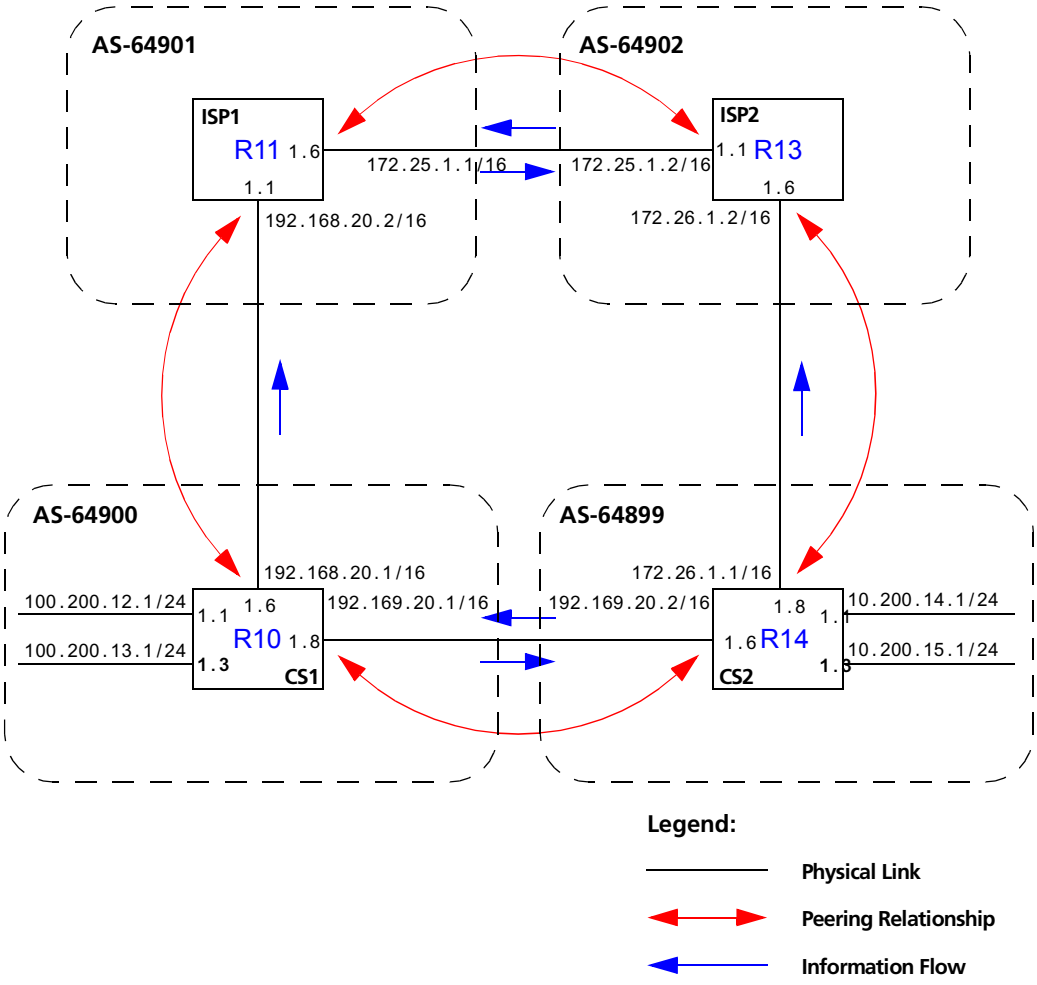

Figure 16-5 Sample BGP configuration (specific community)

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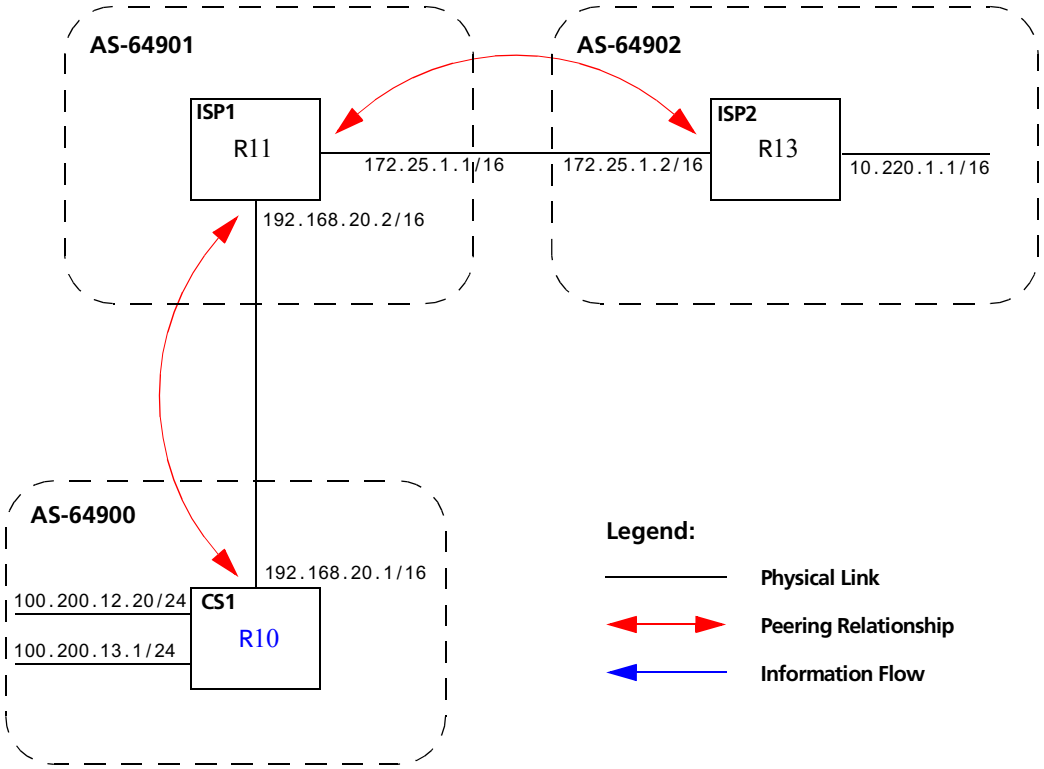

Figure 16-6 Sample BGP configuration (well-known community)

The Community attribute can be used in three ways:

1. In a BGP Group statement: Any packets sent to this group of BGP peers will have the communities attribute in the BGP packet modified to be this communities attribute value from this AS.
2. In an Import Statement: Any packets received from a BGP peer will be checked for the community attribute. The **`optional-attributes-list`** option of the **`ip-router policy create`** command allows the specification of an import policy based on optional path attributes (for instance, the community attribute) found in the BGP update. If multiple communities are specified in the **`optional-attributes-list`** option, only updates carrying all of the specified communities will be matched. If **`well-known-community none`** is specified, only updates lacking the community attribute will be matched.

   Note that it is quite possible for several BGP import clauses to match a given update. If more than one clause matches, the first matching clause will be used; all later matching clauses will be ignored. For this reason, it is generally desirable to order import clauses from most to least specific. An import clause without an **`optional-attributes-list`** option will match any update with any (or no) communities.

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In Figure 16-5, router R11 has the following configuration:

```
#
# Create an optional attribute list with identifier color1 for a community
# attribute (community-id 160 AS 64901)
#
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64901
#
# Create an optional attribute list with identifier color2 for a community
# attribute (community-id 155 AS 64901)
#
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64901
#
# Create a BGP import source for importing routes from AS 64900 containing the
# community attribute (community-id 160 AS 64901). This import source is given an
# identifier 901color1 and sequence-number 1.
#
ip-router policy create bgp-import-source 901color1 optional-attributes-list
    color1 autonomous-system 64900 sequence-number 1
ip-router policy create bgp-import-source 901color2 optional-attributes-list
    color2 autonomous-system 64900 sequence-number 2
ip-router policy create bgp-import-source 901color3 optional-attributes-list
    color1 autonomous-system 64902 sequence-number 3
ip-router policy create bgp-import-source 901color4 optional-attributes-list
    color2 autonomous-system 64902 sequence-number 4
#
# Import all routes matching BGP import source 901color1 (from AS 64900 having
# community attribute with ID 160 AS 64901) with a preference of 160
#
ip-router policy import source 901color1 network all preference 160
ip-router policy import source 901color2 network all preference 155
ip-router policy import source 901color3 network all preference 160
ip-router policy import source 901color4 network all preference 155
```


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In Figure 16-5, router R13 has the following configuration:

```
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64902
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64902
ip-router policy create bgp-import-source 902color1 optional-attributes-list
    color1 autonomous-system 64899 sequence-number 1
ip-router policy create bgp-import-source 902color2 optional-attributes-list
    color2 autonomous-system 64899 sequence-number 2
ip-router policy create bgp-import-source 902color3 optional-attributes-list
    color1 autonomous-system 64901 sequence-number 3
ip-router policy create bgp-import-source 902color4 optional-attributes-list
    color2 autonomous-system 64901 sequence-number 4
ip-router policy import source 902color1 network all preference 160
ip-router policy import source 902color2 network all preference 155
ip-router policy import source 902color3 network all preference 160
ip-router policy import source 902color4 network all preference 155
```

3. In an Export Statement: The **optional-attributes-list** option of the **ip-router policy create bgp-export-destination** command may be used to send the BGP community attribute. Any communities specified with the **optional-attributes-list** option are sent in addition to any received in the route or specified with the group.

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In Figure 16-5, router R10 has the following configuration:

```
#
# Create an optional attribute list with identifier color1 for a community
# attribute (community-id 160 AS 64902)
#
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64902
#
# Create an optional attribute list with identifier color2 for a community
# attribute (community-id 155 AS 64902)
#
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64902
#
# Create a direct export source
#
ip-router policy create direct-export-source 900toanydir metric 10
#
# Create BGP export-destination for exporting routes to AS 64899 containing the
# community attribute (community-id 160 AS 64902). This export-destination has an
# identifier 900to899dest
#
ip-router policy create bgp-export-destination 900to899dest autonomous-system
    64899 optional-attributes-list color1
ip-router policy create bgp-export-destination 900to901dest autonomous-system
    64901 optional-attributes-list color2
#
# Export routes to AS 64899 with the community attribute (community-id 160 AS
# 64902)
#
ip-router policy export destination 900to899dest source 900toanydir network all
ip-router policy export destination 900to901dest source 900toanydir network all
```

In Figure 16-5, router R14 has the following configuration:

```
ip-router policy create bgp-export-destination 899to900dest autonomous-system
    64900 optional-attributes-list color1
ip-router policy create bgp-export-destination 899to902dest autonomous-system
    64902 optional-attributes-list color2
ip-router policy create bgp-export-source 900toany autonomous-system 64900 metric
    10
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64901
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64901
ip-router policy export destination 899to900dest source 899toanydir network all
ip-router policy export destination 899to902dest source 899toanydir network all
```


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Any communities specified with the **optional-attributes-list** option are sent in addition to any received with the route or associated with a BGP export destination.

The community attribute may be a single community or a set of communities. A maximum of 10 communities may be specified.

The community attribute can take any of the following forms:

- Specific community

  The specific community consists of the combination of the AS-value and community ID.

- Well-known-community no-export

  Well-known-community no-export is a special community which indicates that the routes associated with this attribute must not be advertised outside a BGP confederation boundary.

  For example, router R10 in Figure 16-6 has the following configuration:

```
ip-router policy create optional-attributes-list noexport
    well-known-community no-export
ip-router policy create bgp-export-destination 900to901dest
    autonomous-system 64901 optional-attributes-list noexport
ip-router policy export destination 900to901dest source 900to901src
    network all
ip-router policy export destination 900to901dest source 900to901dir
    network all
```

- Well-known-community no-advertise

  Well-known-community no-advertise is a special community indicating that the routes associated with this attribute must not be advertised to other bgp peers. A packet can be modified to contain this attribute and passed to its neighbor. However, if a packet is received with this attribute, it cannot be transmitted to another BGP peer.

- Well-known-community no-export-subconfed

  Well-known-community no-export-subconfed is a special community indicating the routes associated with this attribute must not be advertised to external BGP peers. (This includes peers in other members' autonomous systems inside a BGP confederation.)

  A packet can be modified to contain this attribute and passed to its neighbor. However, if a packet is received with this attribute, the routes (prefix-attribute pair) cannot be advertised to an external BGP peer.

- Well-known-community none

  This is not actually a community, but rather a keyword that specifies that a received BGP update is only to be matched if no communities are present. It has no effect when originating communities.

Notes on Using Communities

When originating BGP communities, the set of communities that is actually sent is the union of the communities received with the route (if any), those specified in group policy (if any), and those specified in export policy (if any).

When receiving BGP communities, the update is only matched if all communities specified in the **optional-attributes-list** option of the **ip-router policy create** command are present in the BGP update. (If additional communities are also present in the update, it will still be matched.)

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16.3.5 Local Preference Examples

There are two methods of specifying the local preference with the **`bgp set peer-group`** command:

- Setting the **`local-pref`** option. This option can only be used for the internal, routing, and IGP group types and is not designed to be sent outside of the AS.
- Setting the **`set-pref`** option, which allows the RS IP routing code (ROSRD) to set the local preference to reflect ROSRD's own internal preference for the route, as given by the global protocol preference value. Note that in this case, local preference is a function of the ROSRD preference and set-pref options.

Figure 16-7 shows a BGP configuration that uses the BGP local preference attribute in a sample BGP configuration with two autonomous systems. All traffic exits Autonomous System 64901 through the link between router R13 and router R11. This is accomplished by configuring a higher local preference on router R13 than on router S12. Because local preference is exchanged between the routers within the AS, all traffic from AS 64901 is sent to R13 as the exit point.

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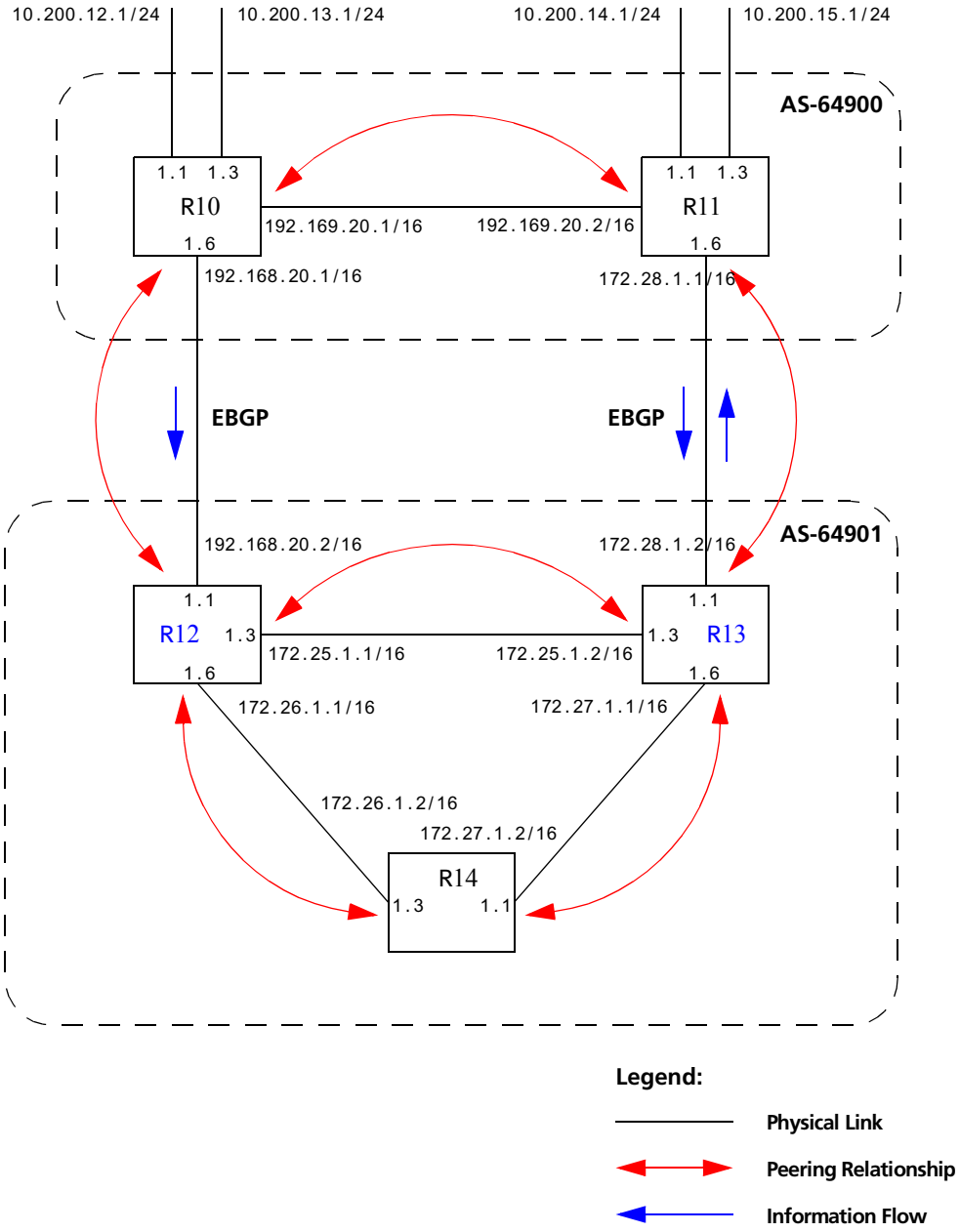

Figure 16-7 Sample BGP configuration (local preference)

The following sections explain how to configure the local preference using the **`local-pref`** and the **`set-pref`** options.

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Using the local-pref Option

For router R12's CLI configuration file, **`local-pref`** is set to 194:

```
bgp set peer-group as901 local-pref 194
```

For router R13, **`local-pref`** is set to 204.

```
bgp set peer-group as901 local-pref 204
```

Using the set-pref Option

The formula used to compute the local preference is as follows:

Local_Pref = 254 – (global protocol preference for this route) + set-pref metric

Note A value greater than 254 will be reset to 254. ROSRD will only send Local_Pref values between 0 and 254.

In a mixed ROSRD and non-ROSRD (or non-GateD) network, the non-ROSRD IBGP implementation may send Local_Pref values that are greater than 254. When operating a mixed network of this type, you should make sure that all routers are restricted to sending Local_Pref values in the range metric to 254.

In router R12's CLI configuration file, the import preference is set to 160:

```
#
# Set the set-pref metric for the IBGP peer group
#
bgp set peer-group as901 set-pref 100
ip-router policy create bgp-import-source as900 autonomous-system 64900 preference 160
```

Using the formula for local preference [Local_Pref = 254 - (global protocol preference for this route) + metric], the Local_Pref value put out by router R12 is 254 - 160+100 = 194.

For router R13, the import preference is set to 150. The Local_Pref value put out by router R13 is 254 - 150+100 = 204.

```
ip-router policy create bgp-import-source as900 autonomous-system 64900 preference 150
```


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Note the following when using the **set-pref** option:

- All routers in the same network that are running ROSRD and participating in IBGP should use the **set-pref** option, and the **set-pref** metric should be set to the same value.

  For example, in Figure 16-7, routers R12, R13, and R14 have the following line in their CLI configuration files:

```
bgp set peer-group as901 set-pref 100
```

- The value of the **set-pref** option should be consistent with the import policy in the network.

  The metric value should be set high enough to avoid conflicts between BGP routes and IGP or static routes. For example, if the import policy sets ROSRD preferences ranging from 170 to 200, a set-pref metric of 170 would make sense. You should set the metric high enough to avoid conflicts between BGP routes and IGP or static routes.

16.3.6 Multi-Exit Discriminator Attribute Example

Multi-Exit Discriminator (MED) is a BGP attribute that affects the route selection process. MED is used on external links to discriminate among multiple exit or entry points to the same neighboring AS. All other factors being equal, the exit or entry point with a lower metric should be preferred. If received over external links, the MED attribute may be propagated over internal links to other BGP speakers within the same AS. The MED attribute is never propagated to other BGP speakers in neighboring autonomous systems.

Figure 16-8 shows a sample BGP configuration where the MED attribute has been used.

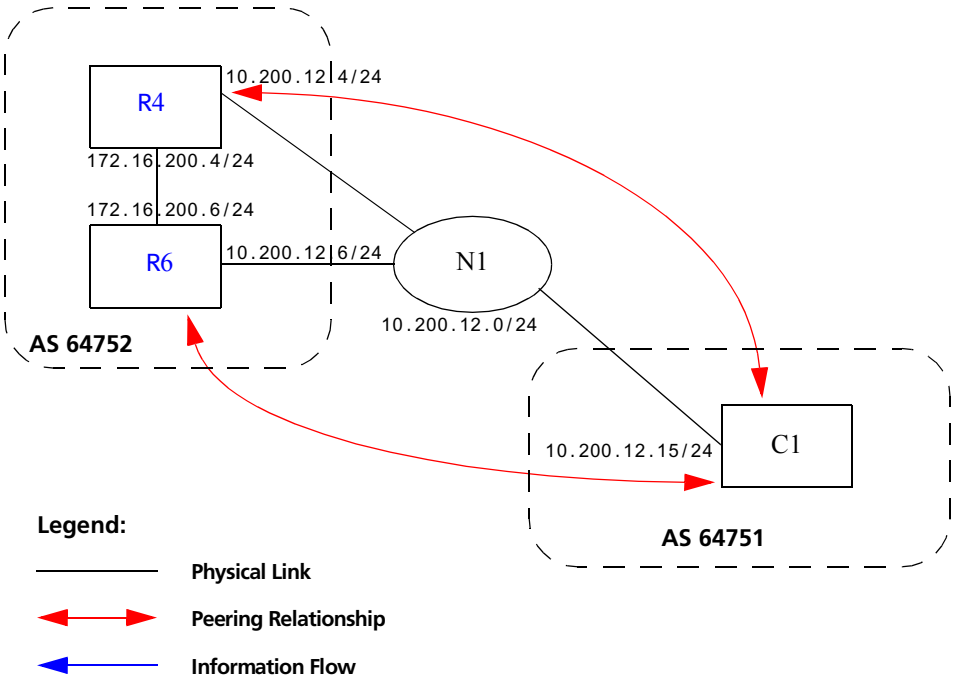

Figure 16-8 Sample BGP configuration (MED attribute)

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Routers R4 and R6 inform router C1 about network 172.16.200.0/24 through External BGP (EBGP). Router R6 announced the route with a MED of 10, whereas router R4 announces the route with a MED of 20. Of the two EBGP routes, router C1 chooses the one with a smaller MED. Thus router C1 prefers the route from router R6, which has a MED of 10.

Router R4 has the following CLI configuration:

```
bgp create peer-group pg752to751 type external autonomous-system 64751
bgp add peer-host 10.200.12.15 group pg752to751
#
# Set the MED to be announced to peer group pg752to751
#
bgp set peer-group pg752to751 metric-out 20
```

Router R6 has the following CLI configuration:

```
bgp create peer-group pg752to751 type external autonomous-system 64751
bgp add peer-host 10.200.12.15 group pg752to751
bgp set peer-group pg752to751 metric-out 10
```

16.3.7 EBGP Aggregation Example

Figure 16-9 shows a simple EBGP configuration in which one peer is exporting an aggregated route to its upstream peer and restricting the advertisement of contributing routes to the same peer. The aggregated route is 212.19.192.0/19.

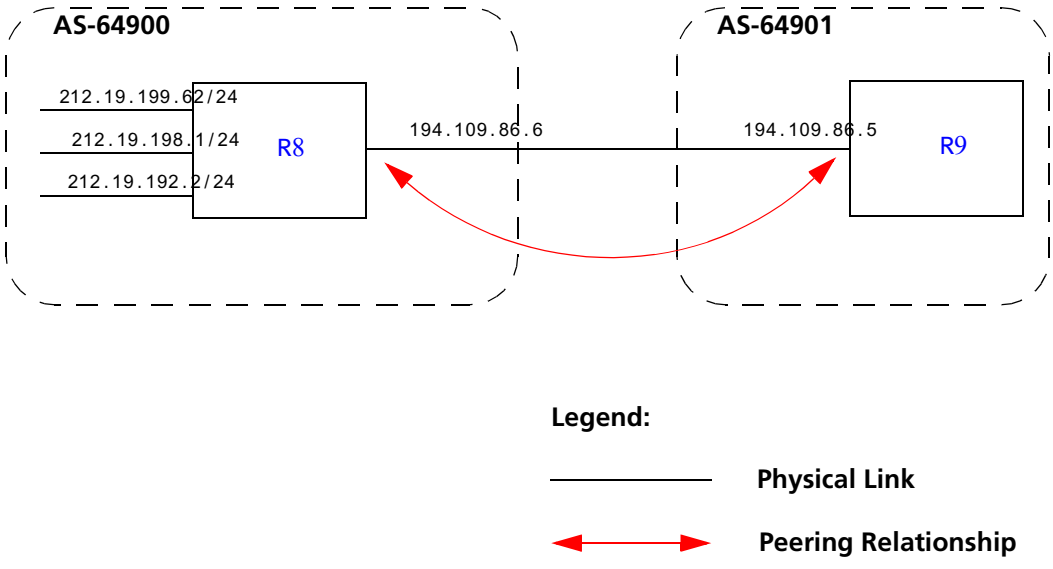

Figure 16-9 Sample BGP configuration (route aggregation)

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Router R8 has the following CLI configuration:

```
interface add ip xleapnl address-netmask 212.19.192.2/24
interface create ip hobbygate address-netmask 212.19.199.62/24 port
    et.1.2
interface create ip xenosite address-netmask 212.19.198.1/24 port et.1.7
interface add ip lo0 address-netmask 212.19.192.1/30
bgp create peer-group webnet type external autonomous system 64901
bgp add peer-host 194.109.86.5 group webnet
#
# Create an aggregate route for 212.19.192.0/19 with all its subnets as
# contributing routes
#
ip-router policy summarize route 212.19.192.0/19
ip-router policy redistribute from-proto aggregate to-proto bgp
    target-as 64901 network 212.19.192.0/19
ip-router policy redistribute from-proto direct to-proto bgp target-as
    64901 network all restrict
```

Router R9 has the following CLI configuration:

```
bgp create peer-group rtr8 type external autonomous system 64900
bgp add peer-host 194.109.86.6 group rtr8
```

16.3.8 Route Reflection Example

In some ISP networks, the internal BGP mesh becomes quite large, and the IBGP full mesh does not scale well. For such situations, route reflection provides a way to alleviate the need for a full IBGP mesh. In route reflection, the clients peer with the route reflector and exchange routing information with it. In turn, the route reflector passes on (reflects) information between clients.

The IBGP peers of the route reflector fall under two categories: clients and non-clients. A route reflector and its clients form a cluster. All peers of the route reflector that are not part of the cluster are non-clients. The RS supports client peers as well as non-client peers of a route reflector.

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Figure 16-10 shows a sample configuration that uses route reflection.

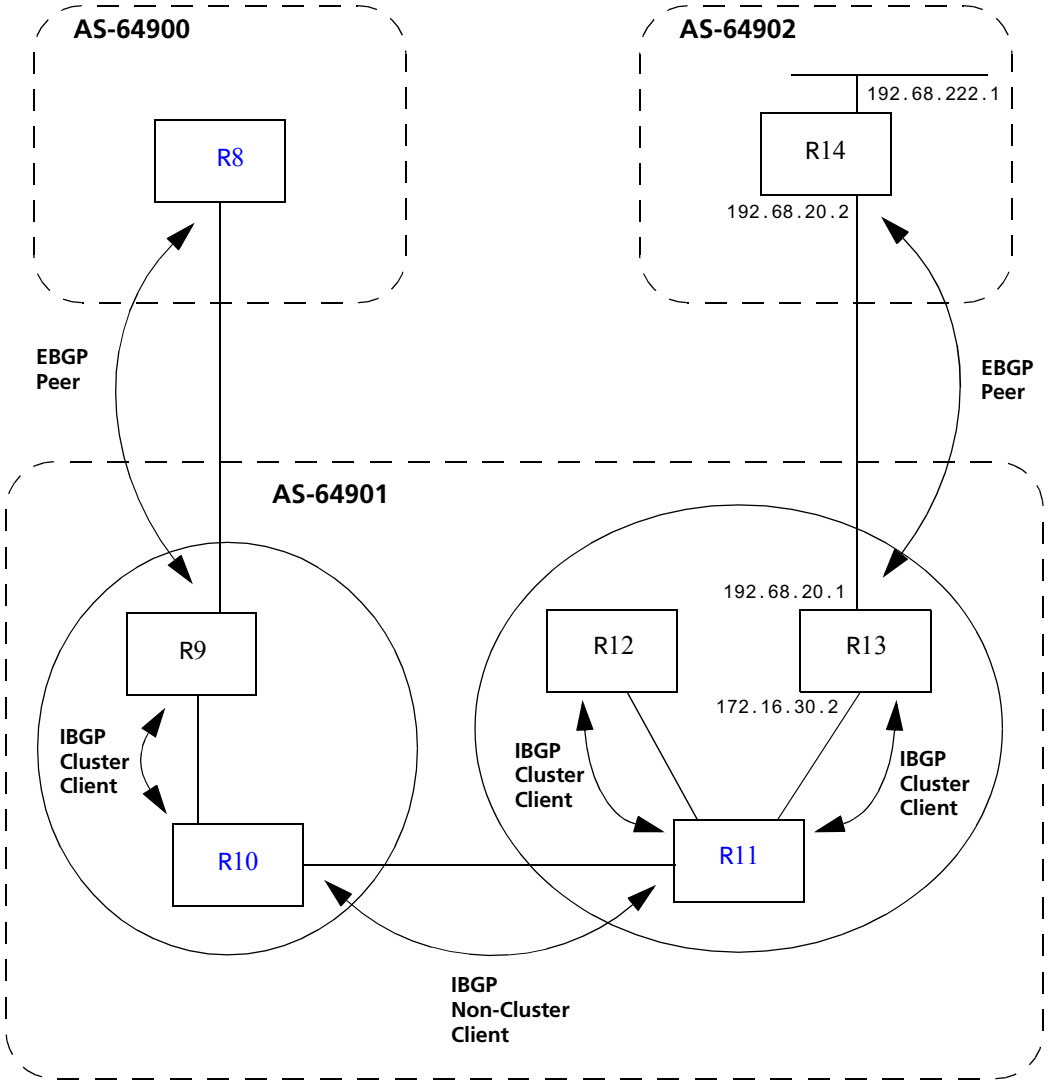

Figure 16-10Sample BGP configuration (route reflection)

In this example, there are two clusters. Router R10 is the route reflector for the first cluster and router R11 is the route reflector for the second cluster. Router R10 has router R9 as a client peer and router R11 as a non-client peer.

The following line in router R10's configuration file causes it to be a route reflector.

```
bgp set peer-group R9 reflector-client
```


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Router R11 has router R12 and router R13 as client peers and router R10 as non-client peer. The following line in router R11's configuration file specifies it to be a route reflector

```
bgp set peer-group rtr11 reflector-client
```

Even though the IBGP Peers are not fully meshed in AS 64901, the direct routes of router R14, that is, 192.68.222.0/24 in AS 64902 (which are redistributed in BGP) do show up in the route table of router R8 in AS64900, as shown below:

```
*******************************************
* Route Table (FIB) of Router 8            *
*******************************************
rtr-8# ip show routes

Destination                Gateway                    Owner     Netif
-----------                -------                    -----     -----
10.50.0.0/16               directly connected         -         en
127.0.0.0/8                127.0.0.1                  Static    lo
127.0.0.1                  127.0.0.1                  -         lo
172.16.20.0/24             directly connected         -         mls1
172.16.70.0/24             172.16.20.2                BGP       mls1
172.16.220.0/24            172.16.20.2                BGP       mls1
192.68.11.0/24             directly connected         -         mls0
192.68.20.0/24             172.16.20.2                BGP       mls1
192.68.222.0/24            172.16.20.2                BGP       mls1
```

The direct routes of router R8, i.e. 192.68.11.0/24 in AS64900 (which are redistributed in BGP), do show up in the route table of router R14 in AS64902, as shown below:

```
*********************************************************
*  Route Table (FIB) of Router 14                        *
*********************************************************
rtr-14# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.50.0.0/16         directly connected   -         en0
127.0.0.0/8          127.0.0.1            Static    lo0
127.0.0.1            127.0.0.1            -         lo0
172.16.20.0/24       192.68.20.1          BGP       mls1
172.16.30.0/24       192.68.20.1          BGP       mls1
172.16.90.0/24       192.68.20.1          BGP       mls1
192.68.11.0/24       192.68.20.1          BGP       mls1
192.68.20.0/24       directly connected   -         mls1
192.68.222.0/24      directly connected   -         mls0
```


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Notes on Using Route Reflection

- Two types of route reflection are supported:
  - By default, all routes received by the route reflector from a client are sent to all internal peers (including the client's group, but not the client itself).
  - If the **`no-client-reflect`** option is enabled, routes received from a route reflection client are sent only to internal peers that are not members of the client's group. In this case, the client's group must itself be fully meshed.

  In either case, all routes received from a non-client internal peer are sent to all route reflection clients.
- Typically, a single router acts as the reflector for a cluster of clients. However, for redundancy, two or more may also be configured to be reflectors for the same cluster. In this case, a cluster ID should be selected to identify all reflectors serving the cluster, using the **`clusterid`** option. Gratuitous use of multiple redundant reflectors is not advised, since it can lead to an increase in the memory required to store routes on the redundant reflectors' peers.
- No special configuration is required on the route reflection clients. From a client's perspective, a route reflector is simply a normal IBGP peer. Any BGP version 4 speaker can be a reflector client.
- It is necessary to export routes from the local AS into the local AS when acting as a route reflector.

  To accomplish this, routers R10 and R11 have the following line in their configuration files:

```
ip-router policy redistribute from-proto bgp source-as 64901 to-proto bgp target-as
     64901
```

- If the cluster ID is changed, all BGP sessions with reflector clients will be dropped and restarted.

16.3.9 BGP Confederation Example

Figure 16-11 shows a BGP configuration where a single AS (AS number 64705) is split into two sub-AS's (64706 and 64707).

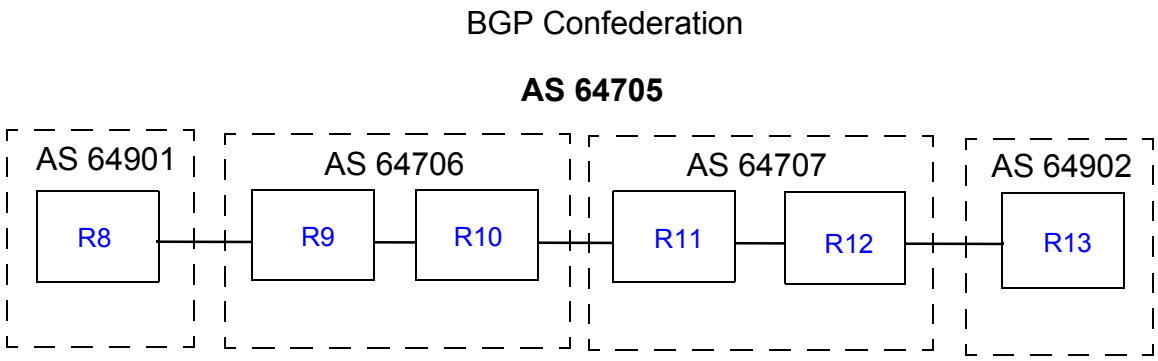

Figure 16-11Sample BGP confederation

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In Figure 16-11, R9 and R10 are included in AS 64706, which is a sub-AS of the confederation with the AS number 64705. R9 has the following CLI configuration:

```
ip-router global set router-id 182.1.1.1
ip-router global set trace-state on
ip-router global set confederation-id 64705
ip-router global set autonomous-system 64706

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group ebgp type external autonomous-system 64901
bgp create peer-group rtr10 type routing autonomous-system 64706
bgp add peer-host 172.16.220.2 group ebgp
bgp add peer-host 172.16.222.2 group rtr10
bgp set peer-host 172.16.220.2 route-map-in 1 group ebgp
bgp set peer-group rtr10 confederation
bgp set peer-group ebgp
bgp start

route-map 1 permit 1 set-metric 50 set-local-preference 1000 set-community
"65000:6500 64000:6000"

ip-router policy redistribute from-proto bgp source-as 64901 to-proto bgp
target-as 64706
```

R10 has the following CLI configuration:

```
ip-router global set router-id 172.16.222.2
ip-router global set autonomous-system 64706
ip-router global set confederation-id 64705
ip-router global set trace-state on

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr9 type routing interface all proto any autonomous-system
64706
bgp create peer-group rtr11 type external autonomous-system 64707
bgp add peer-host 172.16.222.1 group rtr9
bgp add peer-host 172.16.223.2 group rtr11
bgp set peer-group rtr9 confederation
bgp set peer-group rtr11 confederation
bgp start

ip-router policy redistribute from-proto bgp source-as 64706 to-proto bgp target-as
64707
```


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In Figure 16-11, R11 and R12 are included in AS 64707, which is a sub-AS of the confederation with the AS number 64705. R11 has the following CLI configuration.

```
ip-router global set router-id 186.1.1.1
ip-router global set autonomous-system 64707
ip-router global set confederation-id 64705
ip-router global set trace-state on

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr10 type external autonomous-system 64706
bgp create peer-group rtr12 type routing autonomous-system 64707
bgp add peer-host 172.16.223.1 group rtr10
bgp add peer-host 172.16.224.2 group rtr12
bgp set peer-group rtr12 confederation
bgp set peer-group rtr10 confederation
bgp set peer-host 172.16.223.1 group rtr10 multihop
bgp set peer-group rtr10
bgp start

ip-router policy redistribute from-proto bgp source-as 64706 to-proto bgp
target-as 64707
```

R12 has the following CLI configuration:

```
ip-router global set router-id 172.16.71.2
ip-router global set autonomous-system 64707
ip-router global set confederation-id 64705

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr11 type routing autonomous-system 64707
bgp create peer-group rtr13 type external autonomous-system 64902
bgp add peer-host 172.16.224.1 group rtr11
bgp add peer-host 172.16.225.2 group rtr13
bgp set peer-group rtr11 confederation
bgp start

ip-router policy redistribute from-proto bgp source-as 64707 to-proto bgp
target-as 64902 network 3.0.0.0/8
```


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R13 has the following CLI configuration:

```
ip-router global set router-id 13.1.1.1
ip-router global set autonomous-system 64902
ip-router global set trace-state on

bgp create peer-group rtr12 type external autonomous-system 64705
bgp add peer-host 172.16.225.1 group rtr12
bgp start
```

R8 has the following CLI configuration:

```
ip-router global set autonomous-system 64901
ip-router global set router-id 134.141.178.48

ip-router policy create bgp-export-destination rtr9 autonomous-system 64705
ip-router policy create aspath-export-source abc aspath-regular-expression "(.*
701 .*)" origin any protocol all
ip-router policy redistribute from-proto bgp source-as 64751 to-proto bgp target-as
64705 network 3.0.0.0/8

bgp create peer-group rtr9 type external autonomous-system 64705
bgp add peer-host 182.1.1.1 group rtr9
bgp add peer-host 172.16.220.1 group rtr9
bgp start
```

The following examples of the **`bgp show routes`** command show how the as-path attribute is modified as the route is passed through the routers in the BGP confederation.

On R9, the route advertised by R8 is shown with R8's AS number (64901) prepended to the path::

```
r9# bgp show routes all
BGP table : Local router ID is 182.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8               172.16.220.2        50   1000 64901 64751 6379 1 701 80 i
  172.16.222/24      172.16.222.2             100 i
* 172.16.223/24      172.16.222.2             100 i
```


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On R11, the same route is prepended with the sub-AS (64706) to which R10 belongs:

```
r11# bgp show routes all
BGP table : Local router ID is 186.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8               172.16.220.2       50   1000 {64706}64901 64751 6379 1 701 80 i
  172.16.224/24      172.16.224.2             100 i
* 172.16.225/24      172.16.224.2             100 i
```

Note that R11, while in a different sub-AS, is in the same confederation as R10. Within a confederation, routers can "see" other sub-AS's and the sub-AS numbers appear in curly braces ({}) in the path display.

On R13, which is not part of the confederation, the as-path now shows only the AS number of the confederation:

```
r13# bgp show routes all
BGP table : Local router ID is 13.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8               172.16.225.1                64705 64901 64751 6379 1 701 80 i
```

Note As shown in the example outputs for R9 and R11, the next hop, local pref and MED values are passed unchanged through routers in the confederation. The peer-group configuration must include the **multihop** parameter so that the next hop value is passed through the routers. In the above BGP confederation example, the **multihop** parameter should be specified for R11.

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16.3.10 Route Map Example

Figure 16-12 shows a simple BGP configuration in which routes received on R2 for the networks 15.4.0.0/16 and 15.5.0.0/16 are set with community IDs 1:1 and 1:2, respectively. The routes are exported to R8 with these community IDs. On R8, BGP routes with the specified community IDs are to be monitored via BGP accounting (see Section 16.3.11, *"BGP Accounting Examples,"* for more information).

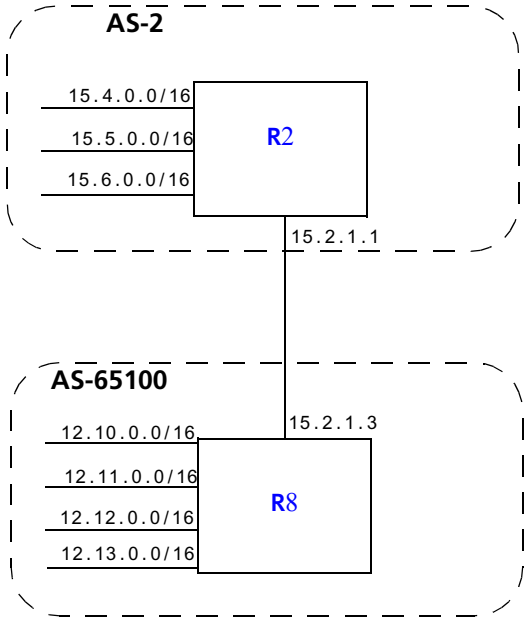

Figure 16-12Sample BGP configuration (route map)

Router R2 has the following CLI configuration:

```
ip-router global set autonomous-system 2
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-community
"1:1"
route-map 1 permit 2 match-prefix network 15.5.0.0/16 set-community
"1:2"
bgp create peer-group tored type external autonomous-system 65100
bgp add peer-host 15.2.1.3 group tored
bgp set preference 99
bgp set peer-group tored route-map-out 1
bgp start
```


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Router R8 has the following CLI configuration:

```
ip-router global set autonomous-system 65100
ip-router policy create community-list 11 "1:1"
ip-router policy create community-list 12 "1:2"
route-map 11 permit 1 match-community-list 11 set-traffic-index 1
route-map 11 permit 2 match-community-list 12 set-traffic-index 2
bgp create peer-group ebgp autonomous-system 2 type external
bgp add peer-host 15.2.1.1 group ebgp
bgp set preference 9
bgp set peer-group ebgp route-map-in 11
bgp start
```

On R8, the **bgp show routes** command for the network interface 15.4.0.0/16 shows the following output:

```
BGP routing table entry for 15.4/16
Path: Best
Source: 15.2.1.1
Advertised to(Tasks):
None:
Local AS: 65100   Peer AS:     2   Age: 1:18:20
NextHop: 15.2.1.1          MED:  -1    Local Preference: -1
AS Path: (65100) 2 IGP (Id 38)
Community: 1:1
```

Note the community list for this network (1:1), as set with the **route-map** command on R2.

16.3.11 BGP Accounting Examples

BGP accounting allows you to collect statistics on specified IP routes. To use BGP accounting, routes must be learned through BGP and be selected routes. In other words, the routes must appear in the routing tables (displayed with the **ip show route** command) and BGP must be the routing protocol for the routes.

Then use the **route-map** command to define route-maps and set up the buckets for collecting the BGP traffic information. (If you are matching communities in the route-map definition, you will need to create the community lists.) Then apply the route-map to the BGP group or peer. Enable BGP accounting on the interface with the **ip enable bgp-actg-on** command, then start accounting with the **ip bgp-accounting start** command.

EBGP Accounting Example

The **set-traffic-index** option of the **route-map** command allows buckets to be set up in which BGP traffic information is collected. In the configuration for R8 shown in Figure 16-12, the routing updates that match the route-map configurations are set to traffic indexes 1, and 2.

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To enable BGP accounting on an interface, enter CLI commands like the following:

```
ip enable bgp-actg-on int1
ip bgp-accounting start accounting
```

To see the BGP accounting information:

```
rs8# ip show interfaces all bgp-actg
Interface:gitoy
Bucket  Packets               Bytes
0       0                     0
1       33760                 2160640
2       33760                 2160640
```

Note For BGP accounting to take effect, the RS must be selecting BGP for the route. Make sure that the preference for BGP is set lower than the preference of other protocols on the RS.

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IBGP Accounting Example

In the example below, routers R1 and R2 are running IBGP/RIP, so they exchange routes automatically. Customer traffic from 13.1.1.5 is being routed to the destination 14.1.1.1/16. The customer is connected to router R1 through the interface 'customerA.' The route to 14.1.0.0/16 is a direct route on router R2 and is learned by R1, which sets the traffic index to 1.

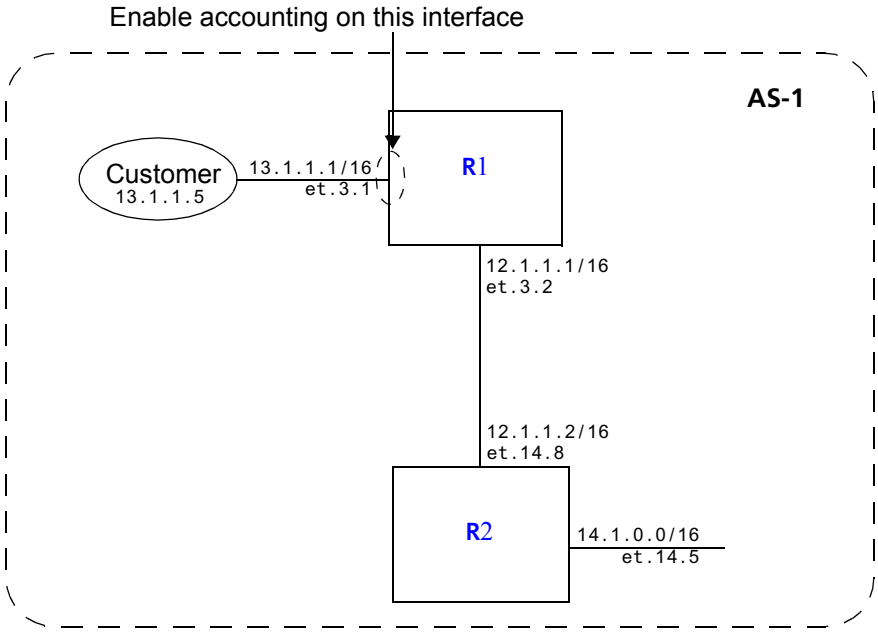

Figure 16-13Sample BGP configuration (accounting)

The following configurations enable BGP accounting on interface 'customerA' to tally the number of bytes and packets sent by the customer.

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R1 has the following configuration:

```
interface create ip toR2 address-netmask 12.1.1.1/16 port et.3.2
interface create ip customerA address-netmask 13.1.1.1/16 port et.3.1

ip enable bgp-actg-on customerA,
ip bgp-accounting start accounting

ip-router global set autonomous-system 1
ip-router global set router-id 10.50.7.1

bgp create peer-group ibgp type routing autonomous-system 1
bgp add peer-host 12.1.1.2 group ibgp
bgp set peer-group ibgp route-map-in 1
bgp set preference 99
bgp start

ip-router policy create community-list list1 "11:11"

route-map 1 permit 1 match-community-list list1 set-traffic-index 1

arp add 12.1.1.2 mac-addr 001122:334455 exit-port et.3.2
arp add 13.1.1.5 mac-addr 00:00:00:00:13:01
```

R2 has the following configuration:

```
interface create ip toR1 address-netmask 12.1.1.2/16 port et.14.8
interface create ip 14.1 address-netmask 14.1.1.1/16 port et.14.5

ip-router global set autonomous-system 1
ip-router global set router-id 10.50.7.9

bgp create peer-group ibgp type routing autonomous-system 1
bgp add peer-host 12.1.1.1 group ibgp
bgp set peer-group ibgp route-map-out 1
bgp start

route-map 1 permit 1 match-prefix network 14.1.0.0/16 set-community "11:11"

arp add 14.1.1.5 mac-addr 00:00:00:00:14:01
```


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Use the **bgp-actg** option with the **ip show interfaces** command to display BGP accounting information for the interface. For example:

```
rs# ip show interfaces customerA bgp-actg

Interface:customerA
Bucket Packets       Bytes
0      0             0
1      111           14430
```

BGP DSCP Accounting

You can choose to have route-specific traffic statistics broken down by DSCP values. The steps are basically the same as in the BGP accounting examples shown previously, except you use the **ip bgp-accounting start dscp-accounting** command to start the collection of statistics.

Figure 16-14 shows a simple BGP configuration in which routes received on R2 for the networks 15.4.0.0/16, 15.5.0.0/16, and 15.6.0.0/16 are exported to R8. On R8, BGP routes from these networks are to be monitored via BGP accounting, with breakout of traffic according to DSCP values.

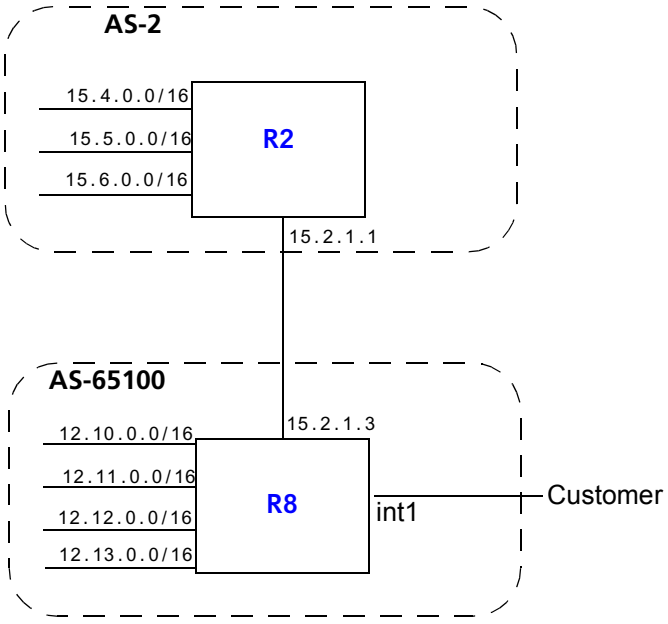

Figure 16-14Sample BGP configuration (DSCP accounting)

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Router R2 has the following CLI configuration:

```
ip-router global set autonomous-system 2
bgp create peer-group tored type external autonomous-system 65100
bgp add peer-host 15.2.1.3 group tored
bgp set preference 99
bgp start
```

Router R8 has the following CLI configuration:

```
ip-router global set autonomous-system 65100
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-traffic-index
10
route-map 1 permit 2 match-prefix network 15.5.0.0/16 set-traffic-index
11
route-map 1 permit 3 match-prefix network 15.6.0.0/16 set-traffic-index
12
bgp create peer-group tor2 autonomous system 2 type external
bgp add peer-host 15.2.1.1 group tor2
bgp set preference 9
bgp set peer-group tor2 route-map-in 1 in-sequence 1
bgp start
```

To enable BGP accounting on the interface ‘int1’ on R8:

```
ip enable bgp-actg-on int1
ip bgp-accounting start dscp-accounting
```


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To view the BGP accounting information collected on R8:

```
r8# ip show interfaces all bgp-actg
Interface:int1
Bucket  DSCP   Packets                Bytes
10      1       239376                15320064
10      2       239201                15308864
10      3       239001                15296064
10      4       238801                15283264
10      5       238601                15270464
10      6       238401                15257664
10      7       238597                15270208
10      8       238401                15257664
10      10      238254                15248256
10      17      238401                15257664
11      11      238189                15244096
11      15      237801                15219264
11      17      239206                15309184
11      20      239387                15320768
12      12      238176                15243264
12      14      237601                15206464
12      18      239001                15296064
```


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17 MPLS CONFIGURATION

Multiprotocol Label Switching (MPLS) is a technology that enables routers to forward traffic based on a simple *label* embedded into the packet header. A router can simply examine the label to determine the next hop for the packet, rather than perform a much more complex route lookup on the destination IP address.While originally designed to speed up layer 3 routing of packets, label-based switching can provide other benefits to IP networks. Riverstone's MPLS allows you to do the following:

- set the path that traffic will take through a network and set performance characteristics for a class of traffic
- add new network routing services without changing the basic forwarding paradigm
- create virtual private network (VPN) tunnels throughout the network (without the need for encryption or end-user applications)

Note The MPLS features described in this chapter are only supported on MPLS-enabled RS line cards. See your Riverstone representative for specific part numbers and applicable RS platforms.

This chapter contains the following sections:

- For an overview of MPLS concepts and terminology, and the MPLS features supported on the RS, see Section 17.1, *"MPLS Architecture Overview."*
- To enable MPLS on the RS switch router, see Section 17.2, *"Enabling and Starting MPLS on the RS."*
- To configure Resource Reservation Protocol (RSVP) signaling for MPLS, see Section 17.3, *"RSVP Configuration."*
- To configure Label Distribution Protocol (LDP) signaling for MPLS, see Section 17.4, *"LDP Configuration."*
- To configure layer 3 label switching, see Section 17.5, *"Configuring L3 Label Switched Paths."* This section includes information on configuring static and dynamic L3 paths, as well as example configurations.
- To configure layer 2 label switching, see Section 17.6, *"Configuring L2 Tunnels."* This section includes information on configuring static and dynamic L2 tunnels, as well as example configurations.
- To use MPLS traffic engineering features, see Section 17.7, *"Traffic Engineering."*

Timesaver Titles shown in blue represent hypertext links to the sections. Click on one of the section titles above to go immediately to that section.

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17.1 MPLS ARCHITECTURE OVERVIEW

A *forwarding equivalence class* (FEC) is a group of IP packets that are forwarded over the same path with the same forwarding treatment. Examples of FECs include:

- unicast packets whose destination address matches a specified IP address prefix
- unicast packets whose destination address matches a specified IP address prefix and whose type of service (ToS) bit matches a specified value
- multicast packets with the same source and destination addresses

In "traditional," non-MPLS networks, each router maps a packet to an FEC based on the destination IP address in the packet's network layer header. Each FEC is then mapped to a next hop. At each hop, the packet is examined and assigned an FEC and a next hop.

In an MPLS network, packets are forwarded in one direction across a *label switched path* (LSP), as shown in Figure 17-1. Labels are the mapping of network layer routing to data link layer switched paths. With MPLS, the assignment of a specific packet to an FEC is only done once—at the first router in the path, the *ingress label switching router* (LSR). Only the ingress LSR[1] in the path needs to analyze the layer 3 header information. If the destination address in the incoming packet matches an entry in the routing table, the appropriate label is applied to the packet and the packet is forwarded on to the next hop. At subsequent hops, intermediate or *transit* LSRs in the path need to only look at the packet label to forward the packet through the MPLS network; no further examination of the packet's network layer header is required.

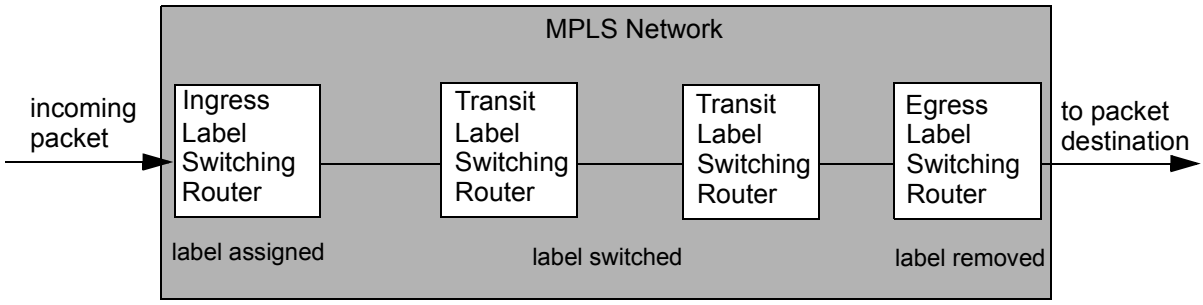

Figure 17-1 MPLS label switched path

At the *egress* LSR at the other edge of the path, the label is stripped off. The packet is then forwarded to its next destination using information in the IP forwarding table. There is one ingress router and one egress router for each LSP. Note that a router cannot be both an ingress and egress LSR for the *same* LSP.

17.1.1 Labels

An MPLS label is a 20-bit integer between 0 and 1048575 that identifies a particular FEC. The label is encapsulated in the packet's layer-2 header, as shown in Figure 17-2.

1. Ingress and egress LSRs are sometimes also referred to as label edge routers (LERs).

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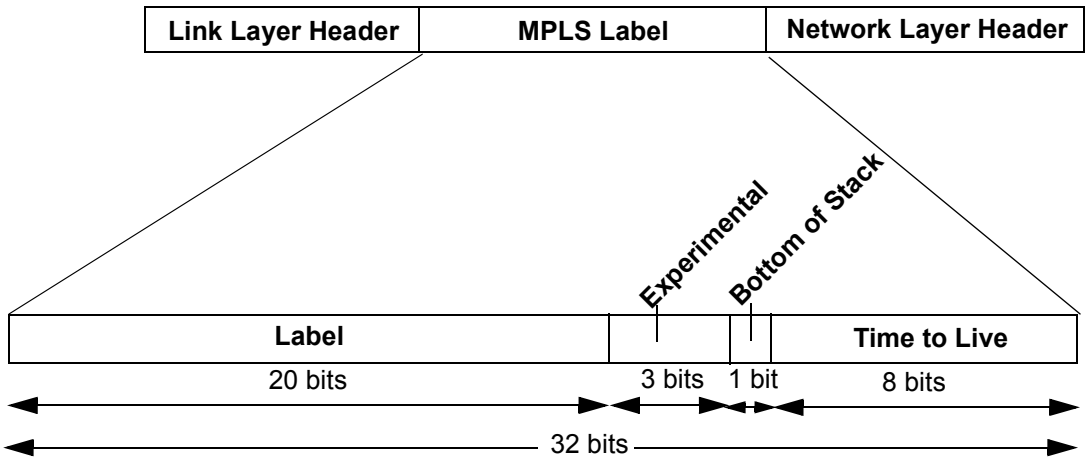

Figure 17-2 Encoding of an MPLS label

A series of two or more MPLS labels, or a *label stack*, can be encoded after the data link and before the network layer header. The top label in the label stack appears earliest in the packet and the bottom label appears last, as shown in Figure 17-3. The network layer header immediately follows the label that has the bottom of stack bit set.

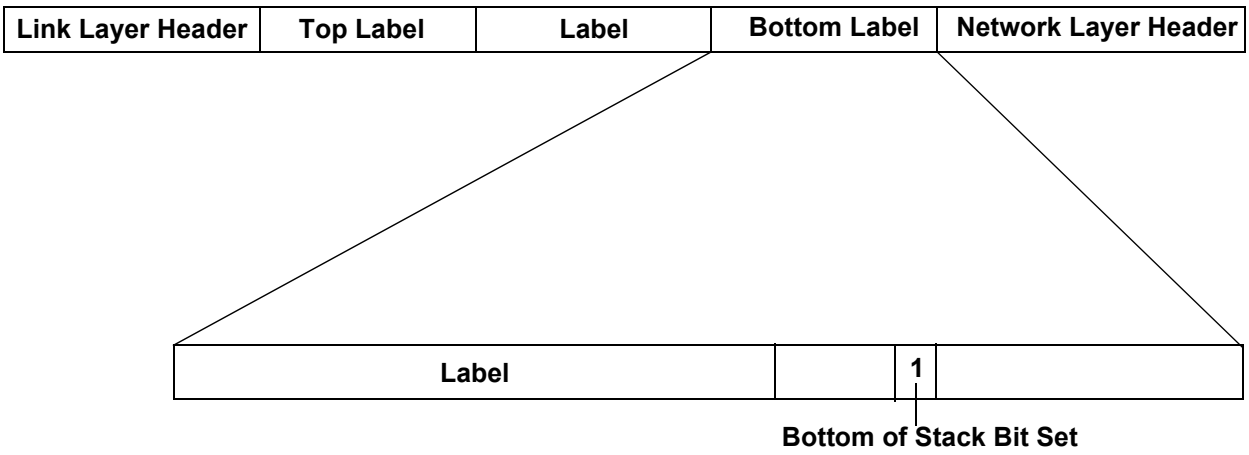

Figure 17-3 MPLS label stack

Forwarding decisions are always based on the top label in the stack. By examining the top label of an incoming packet, each LSR in the LSP determines the following:

- The next hop for the packet
- The operation to be performed on the packet's label stack. It can be one of the following:
  - replace (*swap*) the label at the top of the label stack with a new label
  - remove (*pop*) the top label in the label stack

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- swap the label at the top of the label stack with a new label, then add (*push*) a new label onto the label stack

Label stacks allow for hierarchical routing operations: for example, packets can be routed within an ISP network as well as at a higher, domain level. This allows MPLS packets to be tunneled through backbone networks. For more information about using MPLS tunneling, see Section 17.1.5, *"MPLS Tunnels."*

After a packet is labeled, the packet is forwarded through the network by switching the incoming label value with an outgoing label value at each router. A router that receives a labeled packet checks the label value to determine the next hop for the packet. A label value is relevant only to a particular hop between LSRs; in other words, a label value is significant only to two connected LSRs.

Label values 0 through 15 are reserved and have the following meanings:

Table 17-1 Reserved label values

Label Value	Meaning
0	IPv4 explicit null label. When it is the only label entry (i.e., there is no label stacking), it indicates that the label is popped upon receipt. For example, if the LSP is for IPv4 traffic only, the egress router can signal the penultimate router to use 0 as the final hop label.
1	Router alert label. Packets received with this label value are sent to the CPU for processing.
2	IPv6 explicit null label. When it is the only label entry (i.e., there is no label stacking), it indicates that the label is popped upon receipt. For example, if the LSP is for IPv6 traffic only, the egress router can signal the next to last, or penultimate, router to use 2 as the final hop label.
3	Implicit null label. Used in LDP or RSVP packets to request that the label be popped by the upstream router (penultimate hop label popping). This label should not appear in encapsulation and should not be used in a data packet.
4-15	Unassigned.

Table 17-2 is a summary of the label operations supported on the RS. These label operations are described in the following sections.

Table 17-2 MPLS label operations supported on the RS

Label bindings:	
per interface	if RSVP is used
per router	if LDP is used
Label distribution:	Downstream unsolicited—FEC-label bindings are distributed to peers when the RS is ready to forward packets in the FEC.
Label retention:	Liberal—RS stores all labels learned from peers.
Label advertising:	Ordered—RS advertises FEC-to-label bindings only when it has previously received a label for the FEC from the FEC next-hop or when it is an egress router for the FEC.

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17.1.2 Label Binding

As mentioned previously, in a non-MPLS network the assignment or *binding* of a packet to an FEC is based solely on the destination IP address in the packet header. In an MPLS network, packets that belong to the same FEC follow the same path, although more than one FEC can be mapped to a single LSP. At the ingress LSR, the assignment of a packet to an FEC can be influenced by external criteria and not just by the information contained in the packet header. For example, the following forwarding criteria can also be used to determine label assignment:

- destination unicast routing
- traffic engineering
- whether the packet is a multicast packet
- virtual private network (VPN) configuration
- quality of service (QoS)

The RS supports the following types of FEC-to-label bindings:

- Label bindings can be associated with interfaces. A separate pool of label values is defined for each interface on which MPLS is enabled.
- Label bindings for the router as a whole can be made from a single "global" pool of label values. Labels that are distributed on different interfaces *cannot* have the same value.

The label distribution protocol used determines whether the label bindings are assigned on a per-interface or per-router basis. See *"Label Distribution Protocols"* for more information.

17.1.3 Label Distribution and Management

Before the ingress LSR can label incoming packets for a specific FEC and forward the packets, the LSP must be set up. The binding of the label to the FEC is advertised to neighboring LSRs to establish the LSP. In Figure 17-4, packets sent from R1 to R2 for a particular FEC use the same label binding. In this relationship, R1 is the *upstream* LSR, while R2 is the *downstream* LSR. The downstream LSR determines the binding of a label to an FEC and informs the upstream LSR of the binding through a *label distribution protocol* (discussed later in this section).

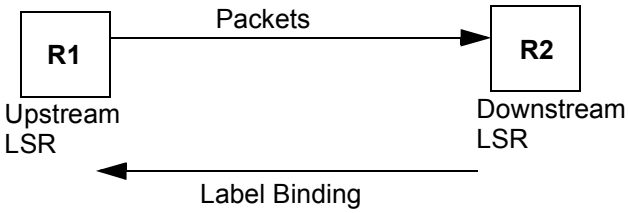

Figure 17-4 Label binding distribution

There are two ways an LSR can *distribute* label bindings:

- An LSR can explicitly request a label binding for a particular FEC from its next hop—this is called *downstream on demand* label distribution.
- An LSR can also distribute label bindings to other LSRs even if it has not been explicitly requested to do so—this is called *downstream unsolicited* label distribution. In *downstream unsolicited* mode, FEC-label bindings are distributed to peers when an LSR is ready to forward packets in the FEC.

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Label Distribution Protocols

An LSP is defined by the set of labels from the ingress LSR to the egress LSR. When an LSR assigns a label to an FEC, it must let other LSRs in the path know about the label and its meaning. Label distribution protocols help to establish the LSP by providing a set of procedures that LSRs can use to distribute labels. Specifically, label distribution protocols allow an LSR to request a label from a downstream LSR so that it can bind the label to a specific FEC. The downstream LSR responds to the request from the upstream LSR by sending the requested label.

The RS supports the following protocols for label distribution:

- *Label distribution protocol* (LDP) is an IETF-defined protocol for LSRs to distribute labels and their meanings to LDP peers. LDP assigns labels from a single pool of labels on a router. To establish an LSP, LDP does not need to rely on routing protocols at every hop along the LSP. LDP allows the establishment of "best effort" LSPs; it does not provide traffic engineering mechanisms. LDP is required for tunneling of layer-2 frames across MPLS networks, as described in Section 17.6, *"Configuring L2 Tunnels."* For more information about configuring LDP on the RS, see Section 17.4, *"LDP Configuration."*
- *Resource reservation protocol* (RSVP) is a protocol that allows channels or paths to be reserved for high bandwidth transmissions. RSVP assigns labels on a per-interface basis. RSVP is used for traffic engineering, which is often required in core or backbone networks where resources are not always available; see Section 17.7, *"Traffic Engineering."* For more information about configuring RSVP on the RS, see Section 17.3, *"RSVP Configuration."*

The LSP must be set up before packets can be forwarded through the MPLS network. Figure 17-5 shows how labels are created and distributed to create an LSP.

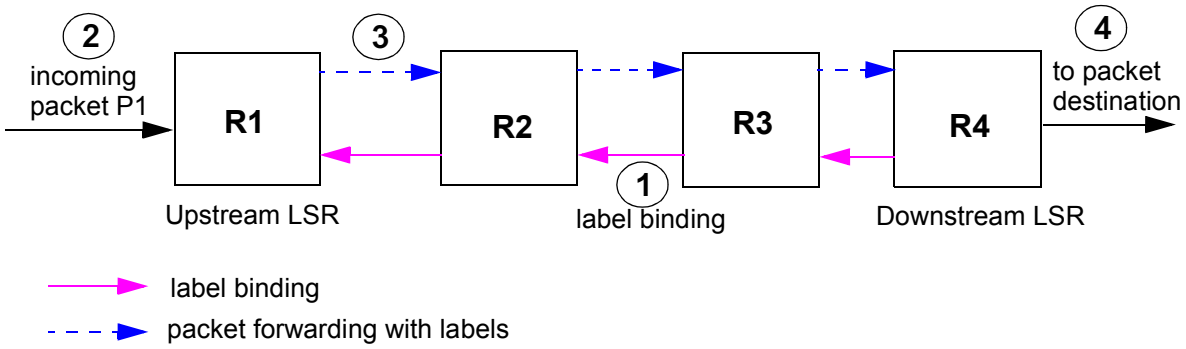

Figure 17-5 LSP creation and packet forwarding

1. Downstream routers distribute label bindings to upstream neighbors.
2. Packet P1 is received at router R1.
3. Router R1 inserts the appropriate label into the packet and forwards it to the next hop. The packet label is examined, replaced and forwarded through the MPLS network. (If R1 does not find a match for this FEC, the packet is forwarded using IP forwarding table information.)
4. The label is removed and forwarded using information in the IP forwarding table at R4.

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Label Advertising Mode

An LSR can advertise label bindings to its peers in one of two modes:

- It can make an independent decision to bind a label to an FEC and distribute that binding to its peers—this is called *independent* mode.
- It can bind a label to a particular FEC if it is the egress LSR for that route or if it has already received a label binding for that FEC from its next hop for the route—this is called *ordered* mode.

The RS supports only ordered label advertising.

Label Retention Mode

An LSR can *store* the label bindings in one of two modes:

- Only label bindings received from next hop downstream LSR peers are stored—this is called *conservative* label retention.
- All label bindings received from peer LSRs are stored, even if the peer is *not* the next hop for a route—this is called *liberal* label retention.

The RS supports only liberal label retention.

17.1.4 Penultimate Hop Popping

The next-to-last LSR in an LSP, or the *penultimate* LSR, can pop the label stack. This process, called penultimate hop popping (PHP), has the following advantage: If the penultimate LSR does not pop the label stack, the egress LSR must do two table lookups to process the packet: first, it must look at the top label in the stack and pop the stack. Then it must either look at the next label in the stack, or if there is no other label in the stack, look up the packet's destination address to forward it. By having the penultimate LSR pop the label stack, there is only a single table lookup performed at each of the egress and penultimate LSRs. By default, RS routers that are PHP LSRs pop the label stack. You can configure the RS egress router to notify the PHP router to *not* pop the label stack.

17.1.5 MPLS Tunnels

You can use MPLS label stacks, instead of network layer encapsulation, to tunnel packets across a backbone MPLS network. Tunneling allows shared resources, such as public networks, to be used to carry private communications. For example, companies can use VPN tunnels to send intranet traffic over the Internet. The advantage that MPLS offers is that the contents of the tunneled data packets do not need to be examined as they proceed through an LSP, as the forwarding of the packets is based only on the attached labels.

Multiple LSPs traveling between the same LSRs across a network can be sent together on a higher-level tunnel LSP. The packets to be sent through the tunnel LSP are considered to be a single FEC by the LSR at the tunnel entrance. This LSR pushes an additional label onto the packets that enter the tunnel LSP before sending the labeled packets to the next hop in the tunnel. When the packets emerge from the tunnel LSP, the top label is popped.

In Figure 17-6, R1 is the ingress LSR for an LSP to the egress LSR, R4. R2 is the entry point for the tunnel LSP and R3 is the exit point for the tunnel LSP.

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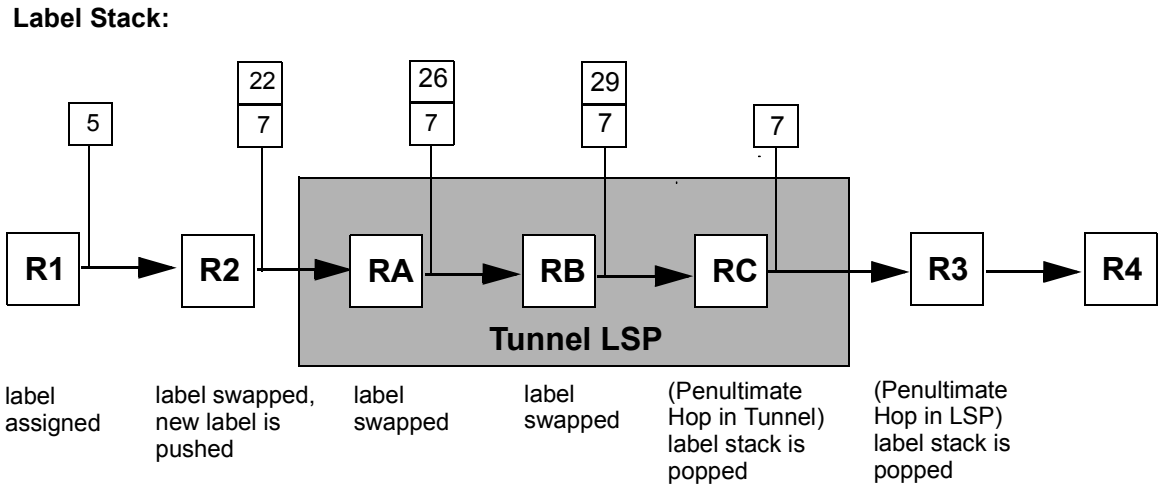

Figure 17-6 LSP tunneling

R1 assigns the label "5" to packets for the LSP to R4. At R2, the label value is swapped from "5" to "7." R2 also determines that the packet destined for R3 must pass through the tunnel. It pushes onto the label stack for the packet a new label "22," a label that is meaningful to the router RA, before forwarding the packet to RA. At the tunnel routers, RA, RB, and RC, label switching is done on the level 2 label. Note that the bottom label in the label stack retains its value as the packet is forwarded through the tunnel LSP; only the top label in the stack is switched.

At RC, the penultimate hop in the tunnel LSP, the label stack is popped before the packet is forwarded out of the tunnel to R3. At R3, the penultimate hop in the LSP, the label stack is popped once again before the unlabeled packet is forwarded to R4.

Note that each LSP is unidirectional. In most cases, it is desirable to have two MPLS LSPs, one going in each direction, to form a logical pipe for the flow of data.

17.1.6 MPLS Table Information

This section describes the various tables that are used to process MPLS packets on the RS.

Output Tag Table (OTT)

The OTT contains information about labels that are to be pushed onto or popped off the MPLS label stack. The OTT entry can also indicate that all labels should be popped off the packet's label stack (Penultimate Hop Popping); this is only done for L3 packets that are tunneled via MPLS. Use the **`mpls show hw-ott-tbl`** command to display entries in the hardware OTT by port and index number. OTT information is also maintained in the software; use the **`mpls show ott-table`** command to display OTT information by interface name or IP address or for all interfaces. The **`mpls show ott-table`** command also displays the index number for the entry in the hardware OTT.

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Incoming Label Map (ILM)

The ILM contains mappings of labels to output channels and ports. Each entry in the ILM provides an index into the OTT. When an MPLS labeled packet arrives at the RS, the router uses the top label to perform a lookup in the ILM table. From the ILM table entry, the RS determines the proper channel and port on which to forward the packet onto the LSP. (If there is no matching ILM table entry for a label value in an incoming packet, the packet is dropped.)

For static LSPs, the ILM entry is created with the label value specified with the **`mpls create l2-static-path`** command. For dynamic LSPs, the ILM entry is created with the label value negotiated via RSVP or LDP.

Use the **`mpls show hw-ilm-tbl`** command to display entries in the hardware ILM by port and index number. ILM information is also maintained in the software; use the **`mpls show ilm-table`** command to display ILM information by interface name or IP address or for all interfaces.

Context Address Memory (CAM)

The CAM is used to map L2 packets to FECs. The RS performs a CAM lookup only if it is the ingress LSR for an LSP. An entry in the CAM table contains the destination and source MAC address, ethertype, VLAN, port of entry (POE), and 802.1q priority. If a CAM entry exists for an L2 packet, the RS retrieves the appropriate OTT index. The OTT entry identified by the OTT index provides the label to be pushed onto the label stack of the MPLS packet. Use the **`mpls show hw-cam-tbl`** command to display entries in the CAM by port and index number.

Table Lookups at Ingress LSRs

On ingress LSRs, incoming packets must be classified into FECs in order to put MPLS labels on the packets. The RS performs OTT lookups to transform packets into MPLS labeled packets. For MPLS labeling of *routed* packets, the OTT lookup is based on the L3 table entry. For MPLS labeling of *bridged* packets, a CAM lookup is first performed using the L2 header information. If there is a matching CAM entry, there is an FEC for these bridged packets and the corresponding OTT index is returned. The OTT entry identified by the OTT index provides the label to be pushed onto the label stack of the MPLS packet.

Table Lookups at Transit LSRs

On transit LSRs, MPLS packets are switched from the input port to the output port of the LSR using only the information in the top label of the MPLS packet. When a labeled packet arrives at the transit LSR, the router looks up the top label in the ILM table to determine the exit port on the LSR for the packet and the corresponding OTT entry. Before the packet leaves the LSR, the top label must be replaced with another label, since labels only have significance between two LSRs that are connected together. The OTT entry determines the new label for the top of the stack. Before the MPLS packet leaves the LSR, the MPLS time to live (TTL) for the top label is decremented, the top label is discarded, and the new label value from the OTT entry is put in its place.

Table Lookups at Egress LSRs

On egress LSRs, the processing of MPLS packets is similar to that done on transit LSRs. The LSR looks up the top label in the ILM table. For any of the following conditions, the MPLS packet is decapsulated and forwarded as a routed or bridged packet:

- the ILM entry indicates that this is the end of an L2 tunnel

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- the END_OF_TUNNEL label is the only label on the label stack
- the ILM entry indicates that this node is at the end of the outermost MPLS domain
- the explicit null label (label value 0) is the only label on the stack

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17.2 ENABLING AND STARTING MPLS ON THE RS

You must enable and start MPLS on all routers and all router interfaces that may become part of an LSP. You must also enable and start either RSVP or LDP on the same routers and router interfaces[2]. When you enable MPLS and either RSVP or LDP on the RS, MPLS uses RSVP or LDP to set up the configured LSPs. For example, when you configure an LSP on the RS with both MPLS and RSVP running, RSVP initiates a session for the LSP. RSVP uses the local router as the RSVP session sender and the LSP destination as the RSVP session receiver. When the RSVP session is created, the LSP is set up on the path created by the session. If the session is not successfully created, RSVP notifies MPLS; MPLS can then either initiate backup paths or retry the initial path.

Note For both RSVP and LDP, you must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

The following CLI commands allow the RS to send and receive labeled packets:

```
! Enable MPLS on router interfaces
mpls add interface int1
mpls add interface int2
! Start MPLS on the router
mpls start
```

In the above example, MPLS is enabled on the interfaces ‘int1’ and ‘int2’. Note that no MPLS processing occurs on the router until MPLS is started with the **`mpls start`** command. This allows you to configure MPLS path information, using other **`mpls`** commands, before starting MPLS.

LSRs can use RSVP to establish and maintain LSPs. As mentioned previously, RSVP is a protocol that allows channels or paths to be reserved for specified transmissions. The following CLI commands enable RSVP on the RS:

```
! Enable RSVP on router interfaces
rsvp add interface int1
! Start RSVP on the router
rsvp start
```

2. You do not need to enable RSVP or LDP if you are configuring *static* LSPs. See Section 17.5.1, *"Configuring L3 Static LSPs."*

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In the above example, RSVP is enabled on the interface ‘int1’. No RSVP processing occurs on the router until RSVP is started with the **rsvp start** command and no LSP creation occurs until MPLS is enabled and started. You can optionally configure RSVP, using the **rsvp set** commands, before starting RSVP. For more information about configuring RSVP, see Section 17.3, *"RSVP Configuration."*

LSRs can also use LDP to distribute labels and their meanings to LDP peers. LDP enables LSR peers to find each other and establish communications. The following CLI commands enable LDP on the RS:

```
! Enable LDP on router interfaces
ldp add interface int2
! Start LDP on the router
ldp start
```

In the above example, LDP is enabled on the interfaces ‘int2’. No LDP processing occurs on the router until LDP is started with the **ldp start** command and no LSP creation occurs until MPLS is enabled and started. You can optionally configure LDP, using other **ldp** commands, before starting LDP. For more information about configuring LDP, see Section 17.4, *"LDP Configuration."*

You cannot enable both RSVP and LDP on the same *interface* on the router, however you can run RSVP and LDP on the same router. For example, a router that is an ingress router for an LSP through a core network might use RSVP signaling on the interface to the core network. The same router can act as a tunnel entry point, through a different interface, for LDP-signaled LSPs.

LDP and RSVP each generate signaling traffic to establish and maintain LSPs. In general, you should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used. For example, issuing the **rsvp add interface all** and **mpls add interface all** commands is an expedient way to enable RSVP and MPLS on all router interfaces. However, if you are using MPLS on a handful of interfaces only, this creates an unnecessary amount of processing overhead and signaling traffic.

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17.3 RSVP CONFIGURATION

Network hosts use the Resource Reservation Protocol (RSVP) to request certain qualities of service from the network for application data flows. Routers also use RSVP to deliver quality of service (QoS) requests to all nodes on the path of a data flow, and to establish and maintain refresh states to provide the requested service. Resources, such as link bandwidth, are reserved on each node along a data path as a result of RSVP requests.

RSVP makes reservations for *unidirectional* data flows, that is, resource requests are made in only one direction. RSVP senders are distinct from receivers, although an application can be both an RSVP sender and receiver at the same time. RSVP operates on top of IP, however it does not transport application data and is only concerned with the QoS of the packets that are forwarded. RSVP is designed to operate with unicast and multicast routing protocols: the routing protocols determine where packets are forwarded, while the RSVP process consults local routing tables to obtain routes.

Note RSVP on the RS supports dynamic signaling for MPLS LSPs only. It does *not* support IP multicast sessions, or resource reservations for real-time audio or video flows.

Note You must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

You must enable both RSVP and MPLS on each router interface on which you want RSVP to run. You also need to enable a unicast routing protocol (for example, OSPF) on the same interface; otherwise, LSPs may not be established between an egress router and all ingress routers. RSVP can be enabled on all router interfaces or on specific router interfaces, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."* The following configuration commands enable and start RSVP and MPLS on the router interface **`to_r1`** on the RS:

```
rsvp add interface to_r1
rsvp start
mpls add interface to_r1
mpls start
```

Note You should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used, as this creates an unnecessary amount of processing overhead and signaling traffic.

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17.3.1 Establishing RSVP Sessions

RSVP includes the following types of messages:

- *Path* messages travel from the potential sender of the data flow to the receiver and include traffic specifications and QoS requirements provided by the sender. Path messages establish the RSVP path between the sender and the path flow destination, storing a *path state* in each router along the way. The path state includes the unicast IP address of the previous hop.
- *Resv* messages travel from the intended receiver of the data flow to the sender and identify the session for which the reservation is being made, the level of QoS required by the receiver, and the label binding for the session. Resv messages use the path state information in each router to follow exactly the reverse path (or paths) that the data packets will use, creating and maintaining a *reservation state* in each router along the path(s).
- *Teardown* messages delete the reservation. Although RSVP uses session timeouts, teardown messages are a more efficient way to release network resources. Either the sender or receiver of a data flow can initiate a teardown request: *PathTear* messages are sent by the sender of the data flow, and *ResvTear* messages are sent by the data flow receiver.

Figure 17-7 illustrates the flow of RSVP Path and Resv messages.

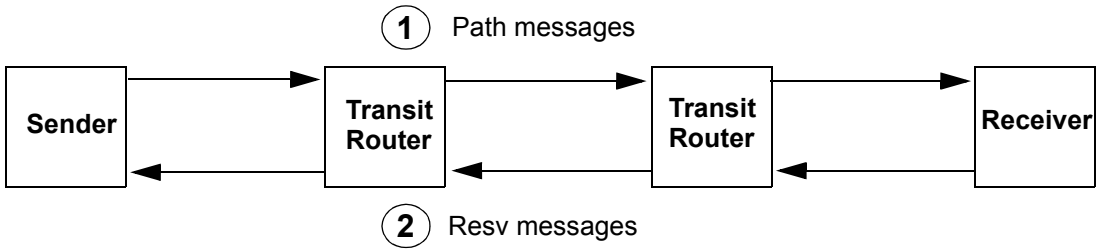

Figure 17-7 RSVP Path and Resv messages

With RSVP, the potential *receiver* of a data flow is responsible for initiating and maintaining the resource reservation for that flow. The receiver passes a QoS request to the local RSVP process. The RSVP protocol then carries the request to all routers upstream to the data sender(s).

During reservation setup, RSVP determines:

- whether the router has sufficient available resources to supply the requested QoS, and
- whether the requestor has the administrative permission required to make the reservation

If either of the above checks fail, RSVP returns an error notification to the requestor. Otherwise, if both checks succeed, the reservation is made at the link layer and the request is propagated upstream toward the appropriate sender.

RSVP uses a *soft state* approach to managing the reservation state in routers, that is, the state is created and periodically refreshed by Path and Resv messages. When a path or reservation state times out, the reservation is deleted or torn down. An explicit teardown message, either PathTear or ResvTear, can also delete the reservation.

Table 17-3 is a summary of the RSVP parameters on the RS and their default values. The commands that you use to enable an RSVP operation or change a default value are also listed.

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Table 17-3 RSVP parameters on the RS

Parameter	Default Value	Command to Change Default Value
Path refresh:		
path refresh interval	30 seconds	**rsvp set global path-refresh-interval**
path multiplier	3	**rsvp set global path-multiplier**
Reservation refresh:		
reservation refresh interval	30 seconds	**rsvp set global resv-refresh-interval**
reservation multiplier	3	**rsvp set global resv-multiplier**
Hello packets:	(Disabled)	**rsvp set interface** <*interface*> **hello-enable**
hello interval	3 seconds	**rsvp set global hello-interval**
hello multiplier	3	**rsvp set global hello-multiplier**
Authentication:	(Disabled)	
MD5 signature		**rsvp set interface** <*interface*> **auth-method md5**
Blockade aging:		
interval	60 seconds	**rsvp set global blockade-aging-interval**
Message aggregation:	(Disabled)	**rsvp set interface** <*interface*> **aggregate-enable**
bundle interval	5 seconds	**rsvp set global bundle-interval**
Message ID extensions:	(Disabled)	**rsvp set interface** <*interface*> **msgid-extensions-enable**
summary refresh interval	3 seconds	**rsvp set global msgid-list-interval**
acknowledgement interval	1 second	**rsvp set global msgack-interval**

The following sections describe the RSVP parameters in more detail.

17.3.2 RSVP Refresh Intervals

As mentioned previously, RSVP soft state management depends upon periodic refreshes of the Path and Resv messages. RSVP Path and Resv refresh messages are sent periodically to refresh the states in neighbor routers and ensure that these states do not time out.

In the following formulas, *lifetime* is how long an RSVP router keeps a path or reservation state as a valid state:

*path-lifetime = path-multiplier * path-refresh-interval*

*resv-lifetime = resv-multiplier * resv-refresh-interval*

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The *path-refresh-interval* and *resv-refresh-interval* are the periods of time between the generation of successive refresh messages by an RSVP neighbor. The *path-refresh-interval* or *resv-refresh-interval* is set locally at each RSVP router; this value is sent to neighbor routers in Path and Resv messages, respectively. The receiving RSVP node uses the values contained in the messages to calculate the *path-lifetime* or *resv-lifetime* for the path or reservation state. On the RS, the default interval for both Path and Resv refreshes is 30 seconds.

The *path-multiplier* and *resv-multiplier* are integers between 1 and 255 that are configured on the local router. On the RS, the default for both multipliers is 3.

For example, if the *path-multiplier* is set locally at 3 and the *path-refresh-interval* received from an RSVP neighbor is 30 seconds, then:

path-lifetime = 3 * 30 = 90 seconds

[*path-multiplier* minus 1] successive Path refresh messages may be lost without the path state timing out. For example, the *path-multiplier* default value on the RS is 3; 2 successive Path refresh messages can be lost without the path state timing out.

On the RS, you can use the **rsvp set global** command to set the values for the Path and Resv refresh intervals and multipliers:

- The **path-refresh-interval** parameter specifies the interval at which RSVP sends out Path messages to the downstream neighbor. The default value is 30 seconds.
- The **resv-refresh-interval** parameter specifies the interval at which RSVP sends out Resv messages to the upstream neighbor. The default value is 30 seconds.
- You can specify a **path-multiplier** parameter value between 1 and 255. The default value is 3.
- You can specify a **resv-multiplier** parameter value between 1 and 255. The default value is 3.

17.3.3 RSVP Hello Packets

The RS supports the sending of RSVP hello packets on a per-interface basis. Sending hello packets allows RSVP routers to detect the loss of RSVP state information of a neighbor node, for example, when a link fails or the neighbor router restarts. RSVP hello packets can detect the state change of a neighbor node more quickly than simply relying on RSVP soft state timeouts. For example, if a link fails, RSVP hello packets can detect the state change in about 20 seconds, compared to several minutes for an RSVP soft state timeout.

When hello packets are enabled on an interface, RSVP sends unicast hello packets to the RSVP neighbor on that interface. On an RS interface, hello packets are sent by default at 3-second intervals. RSVP sessions with a neighbor node are considered to be "down" if hello packets are not received within the following time period:

hello-interval * *hello-multiplier*

On the RS, the default for the *hello-multiplier* is 3. Thus, if hello packets are not received from a neighbor within 9 seconds, that neighbor and its RSVP session are considered to be down.

Sending RSVP hello packets is disabled by default on the RS. You can enable RSVP hello packets on an interface with the **hello-enable** parameter of the **rsvp set interface** command. For example, the following command enables RSVP hello packets on the interface 'int2':

```
rsvp set interface int2 hello-enable
```


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If an RSVP neighbor on the interface does not support hello packets, soft state timeouts are used to detect loss of state information.

By default, RSVP hello packets are sent at 3-second intervals. You can change this interval with the **rsvp set global hello-interval** command. For example, the following command sets the sending of RSVP hello packets to 5-second intervals:

```
rsvp set global hello-interval 5
```

By default, the RSVP hello multiplier is 3. You can change this variable with the **rsvp set global hello-multiplier** command. For example, the following command sets the RSVP hello multiplier to 5:

```
rsvp set global hello-multiplier 5
```

If RSVP hello packets are supported on all neighbor nodes, you can increase RSVP refresh intervals and thereby reduce the refresh overhead. (See Section 17.3.2, *"RSVP Refresh Intervals."*) Refresh operations will consume less CPU and bandwidth, allowing scaling for a larger number of sessions. The time needed for node or link failure detection is not adversely impacted.

17.3.4 Authentication

RSVP messages can be authenticated to prevent unauthorized nodes from setting up reservations. On the RS, RSVP authentication is enabled on a per-interface basis; RSVP authentication is disabled by default. If RSVP authentication is used, all routers connected to the same IP subnet must use the same authentication method and password. Authentication is performed on all RSVP messages that are sent or received on an interface where RSVP authentication is enabled.

RSVP on the RS supports the IETF standard MD5 signature authentication. To set RSVP authentication for an interface on the RS, use the **rsvp set interface** command. Use the **auth-method** parameter to specify the authentication method and the **auth-key** parameter to specify the password.

For example, the following command sets the MD5 password ‘p55717’ for RSVP sessions on the interface ‘int2’:

```
rsvp set interface int2 auth-method md5 auth-key p55717
```

In the above example, if you specify **interface all,** the MD5 password is applied to *all* RSVP sessions on the router.

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17.3.5 Blockade Aging Interval

A "killer reservation" situation occurs when an RSVP reservation request effectively denies service to any other request. For example, an RSVP node attempting (and failing) to make a large reservation can prevent smaller reservation requests from being forwarded and established. On the RS, when there is a reservation error, the offending request enters a *blockade state* for a predetermined amount of time. While a reservation request is *blockaded*, smaller requests can be forwarded and established.

On the RS, the default time that a request can be blockaded is 60 seconds. You can change this interval with the **`rsvp set global blockade-aging-interval`** command. For example, the following command sets the blockade interval to 50 seconds:

```
rsvp set global blockade-aging-interval 50
```

17.3.6 RSVP Refresh Reduction

As described previously, RSVP uses Path and Resv refresh messages to maintain states between RSVP neighbors. Each RSVP session requires that refresh messages be generated, transmitted, received, and processed for each refresh period. Supporting a large number of RSVP sessions presents a scaling problem as the resources required for processing these messages increase proportionally with the number of RSVP sessions.

The RS supports the following features that can reduce the overhead required to process refresh messages on a per-interface basis:

- Message aggregation
- Message ID extensions

The following sections describe how to configure and use these features.

RSVP Message Aggregation

The RS supports the aggregation, or bundling, of multiple RSVP messages on a per-interface basis. Message aggregation helps to scale RSVP by reducing processing overhead and bandwidth consumption. Aggregated RSVP messages can only be sent to RSVP neighbors that support message aggregation. Aggregated RSVP messages must *not* be used if the RSVP neighbor does not support message aggregation.

RSVP message aggregation is disabled by default on the RS. You can enable message aggregation on an interface with the **`aggregate-enable`** parameter of the **`rsvp set interface`** command. For example, the following command enables RSVP message aggregation on the interface 'int2':

```
rsvp set interface int2 aggregate-enable
```


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If message aggregation is enabled on an interface, traffic headed to a specific destination is aggregated at 5-second intervals. You can change this interval with the **rsvp set global bundle-interval** command. For example, the following command sets RSVP message aggregation to 7-second intervals:

```
rsvp set global bundle-interval 7
```

Message ID Extensions

The RS supports message ID extensions, as defined by RFC 2961. These message IDs are generated and processed over a single hop between RSVP neighbors. Enabling message ID extensions provides the following functions:

- *Summary refresh* allows RSVP neighbors to readily identify unchanged messages, thereby reducing refresh message processing. An unchanged message is a message that represents a previously-advertised state, contains the same information as a previously-transmitted message, and is sent over the same path.
- Use of *acknowledgements* between RSVP neighbors to detect message loss and to support reliable RSVP message delivery.

RSVP message ID extensions are disabled by default on the RS. You can enable message ID extensions on an interface with the **msgid-extensions-enable** parameter of the **rsvp set interface** command. For example, the following command enables RSVP message ID extensions on the interface 'int2':

```
rsvp set interface int2 msgid-extensions-enable
```

Summary refresh is used to refresh Path and Resv states without transmitting standard Path or Resv messages. Summary refresh is the periodic transmittal of a list of the message IDs associated with states that were previously advertised in Path or Resv messages. The message ID list reduces the amount of information that must be transmitted and processed in order to maintain RSVP state synchronization. By default, the message ID list is sent at 3-second intervals if message ID extensions are enabled for an interface. You can change this interval with the **rsvp set global msgid-list-interval** command. For example, the following command sets the transmission of the message ID list to 5-second intervals:

```
rsvp set global msgid-list-interval 5
```

Acknowledgements are sent between RSVP neighbors that support message ID extensions. When message ID extensions are enabled, acknowledgements are sent for RSVP messages that advertise state or any other information that was not previously transmitted. Message acknowledgements can be sent in any RSVP message that has an IP destination address that matches the original message generator. Or, the acknowledgement can be sent in a separate acknowledgement message, if no appropriate RSVP message is available. If an acknowledgement is delayed, the corresponding message is retransmitted. To avoid retransmission, the acknowledgement should be sent at minimal

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intervals. On the RS, the default interval for sending message acknowledgements is 1 second. You can change this interval with the **rsvp set global msgack-interval** command. For example, the following command sets the transmission of message acknowledgements to 3-second intervals:

```
rsvp set global msgack-interval 3
```

17.3.7 Displaying RSVP Information

Table 17-4 is a summary of the RSVP session information that you can display on the RS and the CLI commands that you use to display the information.

Table 17-4 RSVP session information

To see this information:	Use this command:
RSVP global, path state block, reservation state block, traffic control state block, session, and neighbor information.	**rsvp show all**
RSVP global parameters	**rsvp show global**
RSVP interface parameters	**rsvp show interface**
RSVP neighbors, next-hop, and number of sessions	**rsvp show neighbors**
RSVP path state block information	**rsvp show psb**
RSVP reservation state block information	**rsvp show rsb**
RSVP session information	**rsvp show session**
RSVP traffic control state block information	**rsvp show tcsb**

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17.4 LDP CONFIGURATION

LDP is a set of procedures and messages that allow LSRs to establish an LSP through a network by mapping network-layer routing information to data-link layer switched paths. The LSP can have an endpoint at a directly attached neighbor or it may have an endpoint at an egress LSR with switching enabled via transit LSRs. LDP supports label distribution for MPLS forwarding along normally-routed paths (as determined by destination-based routing protocols); this is also called MPLS *hop-by-hop forwarding*.

LDP is generally used in applications where traffic engineering is *not* required. In contrast, RSVP is generally used for label distribution and LSP setup where traffic engineering is necessary, primarily in backbone networks. LDP is also used for signaling layer 2 FEC-to-label mappings to tunnel L2 frames across an MPLS network, as discussed in Section 17.6.2, *"Configuring Dynamic L2 Labels."*

You must enable both LDP and MPLS on each router interface on which you want LDP to run. You also need to enable a unicast routing protocol (for example, OSPF) on the same interface; otherwise, LSPs may not be established between an egress router and all ingress routers. LDP can be enabled on all router interfaces or on specific router interfaces, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."* The following configuration commands enable and start LDP and MPLS on the router interface **`to_r1`** on the RS:

```
ldp add interface to_r1
ldp start
mpls add interface to_r1
mpls start
```

Note You must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

Note You should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used, as this creates an unnecessary amount of processing overhead and signaling traffic.

17.4.1 Establishing LDP Sessions

LSRs that use LDP to exchange FEC-label binding information are called LDP *peers*. LDP allows LSRs to automatically discover potential LDP peers. When LDP is started on the RS, the router attempts to discover other LDP peers by sending LDP hello packets out on its LDP-enabled interfaces. LDP hello packets are sent as multicast UDP packets. If multiple LDP-enabled interfaces exist between two adjacent routers, only one LDP session is established between the routers.

An LDP session using a TCP connection is established between LDP peers to exchange the binding information. When an LDP peer is discovered, the LSR attempts to establish an LDP session through the well-known port 646. After session parameters are successfully negotiated between the peers, the session is used for label distribution.

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17.4.2 Monitoring LDP Sessions

In addition to discovering LDP peers, sending hello packets also allows LDP nodes to detect link or peer node failures. When LDP is started, the RS sends out LDP hello packets every 5 seconds by default. The hello message includes a hold time value that tells the router's peers how long to wait for a hello message. Since the hold time is set by each LDP router, its neighbors can assume that a router or link is down if they do not receive a hello packet from the router within the specified hold time. The default hello hold time used by LDP on the RS is 15 seconds. You can use the **`ldp set interface`** command to specify a different hello hold time for LDP peers on a specific interface or on all router interfaces. For example, the following command sets the LDP hello hold time to 20 seconds on the interface 'int1':

```
ldp set interface int1 link-hello-hold-time 20
```

LDP neighbors do not have to set the *same* hold time value. For example, router R1 can set a hold time of 15 seconds, while its neighbor R2 can set a hold time of 20 seconds.

Once an LDP session is established, LDP keepalive packets are used to monitor the status of the session. On the RS, keepalive packets are sent at 10 second intervals and if the LDP peer does not respond in 30 seconds, the session is considered down. The default session timeout on the RS is 30 seconds. You can use the **`ldp set interface`** command to specify a different LDP session timeout for LDP peers on a specific interface or on all router interfaces. For example, the following command sets the LDP session timeout to 40 seconds on the interface 'int1':

```
ldp set interface int1 keepalive-timeout 40
```

Table 17-5 shows the default times used by the RS to monitor LDP sessions on both directly-connected LDP peers and remote LDP peers. (For more information about remote LDP peers, see Section 17.4.3, *"Remote Peers."*)

Table 17-5 Default LDP session monitoring parameters

Session monitoring parameters	Direct-connect LDP peer	Remote LDP peer
Hello Messages:		
Send interval (not configurable - 1/3 of hold time)	5 seconds	5 seconds
Hold time	15 seconds	15 seconds
Session Keepalive Messages:		
Send interval (not configurable - 1/3 of timeout)	10 seconds	10 seconds
Timeout	30 seconds	30 seconds

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17.4.3 Remote Peers

Note that only directly-connected peers are automatically discovered when LDP is started on the RS. If you need the router to establish LDP communications with an LSR that is *not* directly connected, use the **ldp add remote-peer** command to specify the router ID of the remote LSR.

Note The router ID of the remote LDP peer must be the loopback address of the remote router.

You can use the **ldp set remote-peer** command to specify the hold time for hello messages and the timeout for session keepalive messages for remote LDP peers. You can also use the **ldp set interface** command to specify the hello hold time for remote LDP peers.

For example, the following commands specify that LDP communications be established with the remote peer 100.100.100.102, and set a hold time of 60 seconds and a keepalive timeout of 45 seconds for that peer:

```
ldp add remote-peer 100.100.100.102
ldp set remote-peer 100.100.100.102 hello-hold-time 60 keepalive-timeout 45
```

You can use the **remote-hello-hold-time** parameter of the **ldp set interface** command to specify a different hello hold time for remote LDP peers. Setting the hello hold time for a *specific* remote LDP peer (with the **ldp set remote-peer** command) takes precedence. The **ldp set interface all keepalive-timeout** command sets the keepalive timeout for all LDP peers, including remote peers. Setting the keepalive timeout for a specific remote LDP peer (with the **ldp set remote-peer** command) takes precedence.

17.4.4 Loop Detection

With conventional IP forwarding, packets carry a "Time to Live" (TTL) value in their headers. TTL protects against forwarding loops in the network. When a packet passes through a router, its TTL is decremented by 1. If the TTL reaches 0 before the packet reaches its destination, the packet is discarded. Certain LSP segments may not use TTL. To prevent label request messages from looping in LSPs that traverse non-TTL MPLS networks, you can enable loop detection on the RS. When enabling loop detection, you also specify the maximum path vector length (the path vector contains a list of LSRs traversed by the label request or label mapping message). When an LSR encounters a path vector length that reaches the specified limit, a loop is assumed.

For example, the following command enables loop detection on the RS and sets the path vector limit to 100:

```
ldp set global loop-detection-enable path-vector-limit 100
```


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17.4.5 MD5 Password Protection

Since LDP uses TCP as its transport, you can use the IETF standard MD5 signature option to protect LDP session connections. Use the **ldp set md5-password** command to set an MD5 password on a per-router, per-interface, or per-peer basis.

For example, the following command sets the MD5 password 'p55717' for LDP sessions with the peer 100.100.100.102:

```
ldp set md5-password p55717 peer 100.100.100.102
```

In the above example, if you omit the **peer** keyword and IP address, the MD5 password is applied to *all* LDP sessions on the router.

17.4.6 Using LDP Filters

With MPLS, there is no way to restrict which FECs are or are not bound to labels. You can, however, create and apply LDP filters that restrict the label *bindings* that are sent from downstream LSRs to upstream LSRs. You can also create and apply LDP filters that restrict the label *requests* that an upstream LSR can send to a downstream LSR.

If an upstream LSR does not have label binding information for a specific FEC, it will route packets based on information in the IP routing table. However, if there are several paths of equal cost to the same destination, LDP filters can exclude next-hops from considerations.

On the RS, you can define an LDP filter for:

- outgoing label requests—use the **ldp add export-filter request** command.
- incoming label requests—use the **ldp add import-filter request** command.
- outgoing label bindings—use the **ldp add export-filter mapping** command.
- incoming label bindings—use the **ldp add import-filter mapping** command.

Note A filtered *incoming* label binding will still appear in the LDP input label database (displayed with the **ldp show database verbose** command) on the local router, but will not be considered for LSP establishment. A filtered *outgoing* label binding is not advertised to the specified neighbor LSR, although it will still be advertised to other LDP neighbors and considered by the local router for LSP establishment.

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The following shows LDP filter commands configured on the router rs1. The first command specifies that bindings for 6.6.6.6/32 from the neighbor router 6.6.6.6 are *not* to be used for LSP establishment. The second command allows all other bindings from the same neighbor router to be accepted and used for LSP establishment. Note that the more restrictive filter command has the lower sequence number and will be executed first.

```
rs1(config)# ldp add import-filter mapping network 6.6.6.6/32 restrict neighbor 6.6.6.6
sequence 1
rs1(config)# ldp add import-filter mapping network all neighbor 6.6.6.6 sequence 2
```

Note that if you run the **`ldp show database verbose`** command on rs1 (see the following example), the label binding for 6.6.6.6/32 appears in router rs1's LDP database, but it is marked as "Filtered" (shown in boldface in the example) and is therefore not considered on rs1 for LSP establishment.

```
rs1# ldp show database verbose

Input label database, 1.1.1.1:0-6.6.6.6:0
  Label     Prefix
   2051     1.1.1.1/32
            State:Active
   2052     3.3.3.3/32
            State:Active
     16     6.6.6.6/32
            State:Active, Filtered

Output label database, 1.1.1.1:0-6.6.6.6:0
  Label     Prefix
   2049     3.3.3.3/32
            State:Active
     16     1.1.1.1/32
            State:Active


Input label database, 1.1.1.1:0-3.3.3.3:0
  Label     Prefix
   2050     1.1.1.1/32
            State:Active
     16     3.3.3.3/32
            State:Active

Output label database, 1.1.1.1:0-3.3.3.3:0
  Label     Prefix
   2049     3.3.3.3/32
            State:Active
     16     1.1.1.1/32
            State:Active
```


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You can also define an LDP prefix filter with the **ldp add prefix-filter** command. Once defined, the prefix filter can be used in multiple LDP filter commands. For example, if you want to restrict both outgoing and incoming label requests for certain IP addresses, define an LDP prefix filter first.

In the following example, the **ldp add prefix-filter** command defines a prefix filter for the host node 10.10.10.101. The subsequent commands use the prefix filter to prevent requests or bindings for 10.10.10.101 from being sent to other LDP routers.

```
rs(config)# ldp add prefix-filter 101serv network 10.10.10.101/32 host-net
rs(config)# ldp add export-filter request restrict prefix-filter 101serv neighbor
1.1.1.1 sequence 1
rs(config)# ldp add export-filter mapping restrict prefix-filter 101serv neighbor
1.1.1.1 sequence 1
```

17.4.7 Displaying LDP Information

Table 17-6 is a summary of the LDP session information that you can display on the RS and the CLI commands that you use to display the information.

Table 17-6 LDP peer and session information

To see this information:	Use this command:
LDP global, interface, neighbor, and session parameters, and input and output labels for each LDP session	**ldp show all**
Input and output labels that are exchanged for each LDP session	**ldp show database**
LDP global parameters	**ldp show global**
LDP interface parameters, LDP neighbors on interface, and label space identifier being advertised on interface	**ldp show interface**
Interface on which LDP neighbor was discovered and label space identifier advertised by neighbor	**ldp show neighbor**
LDP session state information. Verbose option shows session connection parameters as well as list of next-hop addresses received on the session.	**ldp show session**

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17.5 CONFIGURING L3 LABEL SWITCHED PATHS

The RS supports two basic types of LSPs:

- *Static* LSPs require that you configure all routers and assign all labels in the path. This is similar to configuring static routes on the router, and there is no reporting of errors or statistics. MPLS must be enabled. No signaling protocol is used, so you do not need to enable RSVP or LDP.
- *Dynamic* LSPs (also called signaled LSPs) use RSVP to set up the path and dynamically assign labels. On the ingress LSR, you configure the LSP as well as enable MPLS and RSVP. On all other LSRs in the dynamic LSP, you only need to enable MPLS and RSVP.

17.5.1 Configuring L3 Static LSPs

In a static LSP, *each* router in the path must be configured with static forwarding information. You can specify label values between 16 and 1024. No signaling protocol is used. MPLS must be enabled on all routers, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."*

This section describes how to configure the ingress, transit, and PHP LSRs for a static LSP. (For a detailed example of how to configure a static path on an RS router, see Section , *"L3 Static Path Configuration Example."*)

Ingress LSR Configuration

Use the **`mpls create static-path`** and **`mpls set static-path`** commands to configure a static LSP on the ingress RS. When configuring the static LSP on the ingress LSR, you specify:

- destination IP address for the static path
- label value (between 16-1024) to be pushed onto the top of the label stack
- next-hop IP address (gateway) for the path

For example, the following command creates the static path SP1 on the ingress LSR. Packets to the destination 50.1.1.1 are assigned the label value 50 and are sent out on the next-hop 10.1.1.5.

```
mpls create static-path SP1 to 50.1.1.1 push 50 gateway 10.1.1.5
```

Transit LSR Configuration

In a static LSP, transit LSRs can change (*swap*) the label value at the top of the label stack. Use the **`mpls set interface`** command to configure the static LSP on the transit RS. When configuring the static LSP on the transit LSR, you specify:

- the incoming interface or IP address for the path
- the next-hop interface or IP address for the path
- the incoming label value and one of the following actions to be taken on the label (the *label map*):
  - swap the incoming label with a specified outgoing label value
  - pop the top value on the label stack
  - push a new label value on the top of the label stack

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For example, the following command on a transit LSR looks at packets arriving on the interface MPLS-R2IN. Packets that have a label value of ‘50’ have their labels replaced by the value ‘100’ before they are sent to the next-hop IP address 20.1.1.2.

```
mpls set interface MPLS-R2IN label-map 50 swap 100 next-hop 20.1.1.2
```

PHP LSR Configuration

In a static LSP, the PHP LSR removes (pops) the label stack and then forwards the packet to the egress LSR. Use the **mpls set interface** command to configure the static LSP on the PHP RS. When configuring the static LSP on the PHP LSR, you specify:

- the incoming interface or IP address for the path
- the next-hop interface or IP address for the path
- the incoming label value to be popped from the label stack (normally, this would be the *only* label in the stack)

For example, the following command on a PHP LSR looks at packets arriving on the interface MPLS-R3IN. Packets that have a label value of ‘100’ have their label popped before they are sent to the next-hop IP address 30.1.1.2.

```
mpls set interface MPLS-R3IN label-map 100 pop next-hop 30.1.1.2
```

L3 Static Path Configuration Example

In the example shown in Figure 17-8, the RS router R1 is an ingress LSR for a static path. For incoming traffic, the RS looks up the destination IP address in its routing table. If a path has been configured for the destination address, the appropriate label is pushed on the packet and the packet is forwarded on to the next hop. For traffic destined for the 50.1/16 network, the label ‘50’ is assigned by R1 before forwarding to the next-hop LSR at 10.1.1.2, in this case, another RS router, R2, which is also the PHP LSR.

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Timesaver Click on the router name (in blue) to see the corresponding configuration.

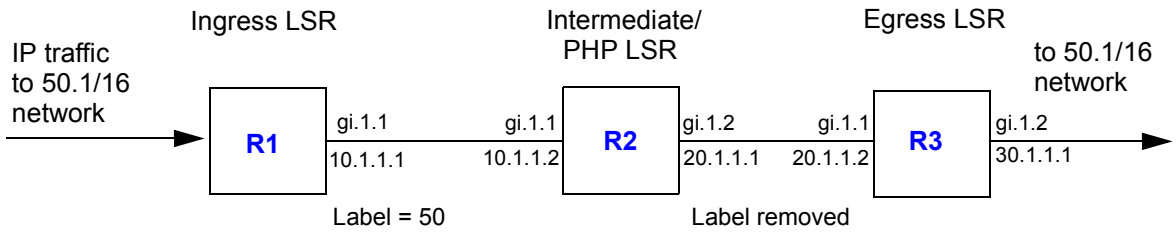

Figure 17-8 L3 static label switched path

Router R1 has the CLI configuration shown below. Note the **push** parameter in the **mpls create static-path** command, which assigns the label '50' to packets destined for 50.1/16.

```
! Create the MPLS interface on this router
interface create ip MPLS-R1OUT address-netmask 10.1.1.1/16 port gi.1.1
! Enable MPLS on the router interfaces
mpls add interface MPLS-R1OUT
! Create a policy to filter traffic to 50.1.0.0/16
mpls create policy POL1 dst-ipaddr-mask 50.1.0.0/16
! Create the static path and assign the label 50 to packets that will travel this path
mpls create static-path SP1 to 50.1.1.1 push 50 gateway 10.1.1.2
! Apply the policy POL1 to this static path
mpls set static-path SP1 policy POL1
! Enable MPLS on this router
mpls start
```


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At router R2, packets arriving on interface MPLS-R2IN that are labeled ‘50’ are assigned the label ‘100’ and forwarded to the next-hop router (R3) at 20.1.1.2. Note the **mpls set interface** command in the following configuration for R2:

```
! Create the MPLS interfaces on this router
interface create ip MPLS-R2IN address-netmask 10.1.1.1/16 port. gi.1.1
interface create ip MPLS-R2OUT address-netmask 20.1.1.1/16 port gi.1.2
! Enable MPLS on the router interfaces
mpls add interface MPLS-R2IN
mpls add interface MPLS-R2OUT
! Configure swapping of labels and next-hop
mpls set interface MPLS-R2IN label-map 50 pop next-hop 20.1.1.2
! Enable MPLS on this router
mpls start
```

Router R3 is the egress label edge router in the path. At the egress router, the label is stripped off before the packet is forwarded to its next destination. At router R3, the packets arriving on interface MPLS-R3IN that are labeled ‘100’ will have the label stripped off before the packets are sent to the next-hop. Router R3 has the following configuration:

```
! Create the MPLS interfaces on this router
interface create ip MPLS-R3IN address-netmask 20.1.1.1/16 port. gi.1.1
interface create ip MPLS-R3OUT address-netmask 30.1.1.1/16 port gi.1.2
! Enable MPLS on the router interfaces
mpls add interface MPLS-R3IN
mpls add interface MPLS-R3OUT
! Enable MPLS on this router
mpls start
```

In the above example, a policy is defined at the ingress router (R1) to filter traffic that is directed onto the static path. There are other ways that you can send traffic on a path, including IGP shortcuts. (See Section 17.7.3, *"IGP Shortcuts."*)

You can use the **mpls show static-paths** command to display the MPLS static path information. On router R1, the following is displayed for the configured static path:

```
R1# mpls show static-paths all

Ingress LSP:
LSPname                  To              From            State LabelIn  LabelOut
SP1                      50.1.1.1        7.7.7.7         Up    -        50
```


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You can use the **mpls show policy** command to display information on MPLS policies. All configured policies are shown; policies that are applied to LSPs are shown to be "INUSE." The following shows an example of the output from router R1; note that the policy 'POL1' is shown to be "INUSE."

```
R1# mpls show policy all
Name        Type Destination     Port   Source        Port   TOS Prot  Use
----------- ---- --------------- ------ ------------- ------ --- ----- -----
POL1        L3   50.1.0.0        any    50.1.0.0      any    any IP    INUSE
```

You can also use the **ip-policy show** command to display information on IP policies, including MPLS policies. Only active policies (MPLS policies that are applied to LSPs) are shown.The following is an example of the output on router R1:

```
R1# ip-policy show all

--------------------------------------------------------------------------------
IP Policy name     : MPLS_PBR_SP1
Applied Interfaces : all-IP-interfaces local-policy
Load Policy        : first available
Health Check       : disabled

ACL          Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK Prot ORIG AS
---          --------------     -------------      -------   -------   --- -------- ---- -------
MPLS_ACL_POL1anywhere           50.1.0.0/16        any       any       any  None     IP

                                                       Next Hop Information
                                                       --------------------
 Seq   Rule   ACL          Cnt      Action       Next Hop        Cnt      Last
 ---   ----   --------     ---      -----------  --------        ---      ----
 10    permit MPLS_ACL_POL1 0        Policy First 10.1.1.1         0        Dwn
```

Note that in the above output 'MPLS_PBR_SP1' refers to the name of the LSP, which in this configuration example is 'SP1.' Similarly, the ACL 'MPLS_ACL_POL1' refers to the name of the policy, which in this configuration example is 'POL1.'

17.5.2 Configuring L3 Dynamic LSPs

With dynamic LSPs, you configure the LSP on the ingress router only. The ingress router sends RSVP signaling information to other LSRs in the path in order to establish and maintain the LSP. Labels are dynamically assigned on the LSRs.

There are two types of dynamic LSPs:

- *Explicit*: You configure the LSP on the ingress router. The sequence of other routers in the path can be specified. The path can be *strict* (the path must go through the specified routers and must not include other routers) or *loose* (the path can include other routers or interfaces). On the RS, strict is the default when configuring an explicit path. The ingress router uses signaling to pass forwarding

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information to each router in the LSP. In non-MPLS networks, explicit routing of packets requires the packet to carry the identity of the explicit route. With MPLS, it is possible to have packets follow an explicit route by having the label represent the route.

With an explicit LSP, each LSR in the path does *not* independently choose the next hop. Explicit LSPs are useful for policy routing or traffic engineering.

- *Constraint-based*: You configure the LSP path constraints on the ingress router. The ingress router calculates the entire path or part of the LSP. RSVP is then used to establish the LSP. All routers must be running either the IS-IS or OSPF routing protocol with traffic engineering extensions enabled.

  For information on configuring constraint-based LSPs, see Section 17.7, *"Traffic Engineering."*

17.5.3 Configuring an Explicit LSP

As mentioned previously, all LSRs in a dynamic LSP use RSVP to establish and maintain the LSP. Therefore, all LSRs must enable RSVP in addition to MPLS. See Section 17.2, *"Enabling and Starting MPLS on the RS."*

You configure an explicit LSP only on the ingress router. Configuring an explicit LSP on the ingress router is a two-step process:

1. Create one or more explicit paths. You can specify some or all transit LSRs in the path. For each transit LSR you specified, you designate whether the route from the previous router to this router is direct and cannot include other routers (*strict* route) or whether the route from the previous router to this router can include other routers (*loose* route).
2. Create the LSP, specifying the previously created explicit paths as either the *primary* or *secondary* path. The secondary path is the alternate path to the destination and is used if the primary path can no longer reach the destination. If the LSP switches from the primary to the secondary path, the LSP will revert back to the primary path when it becomes available.

Configuring an Explicit Path

Use the **`mpls create path`** and **`mpls set path`** commands to configure an explicit path. When configuring an explicit path, you specify the following:

- maximum number of hops for the path
- hop number and IP address of transit routers in the path
- whether the route to the transit router is strict or loose

The following is an example of configuring an explicit path on the RS:

```
mpls create path 567 num-hops 3
mpls set path 567 hop-num 1 ip-addr 30.1.1.1
mpls set path 567 hop-num 2 ip-addr 30.1.1.2
mpls set path 567 hop-num 3 ip-addr 31.1.1.2
```

The **`mpls create path`** command shown above creates an explicit path 567 with a total of 3 hops. The **`mpls set path`** commands identify each of the three hops in the explicit path. By default, the path is *strict*—the path *must* go through the specified hop addresses. (To specify a loose route, include the option **`type loose`**.)

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Configuring the LSP

You can then specify the explicit path as the primary or secondary path for the LSP by specifying the parameter **primary** or **secondary** with the **mpls set label-switched-path** commands. For example, the **mpls create label-switched-path** command shown below creates an LSP L1 to the destination address 100.1.1.1. The **mpls set label-switched-path** command specifies the explicit path 567 as the primary path for the LSP:

```
mpls create label-switched-path L1 to 100.1.1.1 no-cspf
mpls set label-switched-path L1 primary 567 adaptive
```

Note When configuring an explicit LSP, specify the **no-cspf** parameter. Otherwise, the LSP waits indefinitely for a valid constrained shortest path first (CSPF) response.

You can configure the same parameters for the LSP or for the explicit path. You configure parameters for an LSP with the **mpls create label-switched-path** or **mpls set label-switched-path** commands; the parameters you configure at this level apply to *all* paths in the LSP. You configure parameters for an explicit path by specifying the **primary** or **secondary** path with the **mpls set label-switched-path** command; the parameters you configure at the explicit path level apply only to that path. If you configure the same parameter at both the LSP and the explicit path level, the explicit path configuration takes precedence.

Table 17-7 shows the parameters that you can configure for an LSP or for each explicit path (primary or secondary). Some of the parameters are described in more detail following the table. Remember that if you configure the same parameter for both an LSP and an explicit path, the explicit path configuration takes precedence. Also note that certain parameters are only configurable for the LSP.

Table 17-7 LSP and explicit path parameters

Parameter	Description	LSP	Path
adaptive	LSP waits for a recalculated route to be set up before tearing down the old LSP. Disabled by default. (See *"Policies"*.)	X	X
admin-group	Specifies whether administrative groups are included or excluded on LSP (see **exclude** and **include** parameters). All administrative groups are included by default. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X
bps	Bandwidth, in bits, to be reserved with RSVP. (See *"Bandwidth"*.)	X	X
class-of-service	Sets a fixed CoS value for all packets entering the LSP. (See *"CoS Value"*.)	X	X
disable	Disables the LSP or path.	X	X

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Table 17-7 LSP and explicit path parameters

Parameter	Description	LSP	Path
exclude	Exclude specified administrative groups. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X
from	Address of the local router (default is the local router ID).	X	
hop-limit	The maximum number of hops, including the ingress and egress LSR, allowed in this LSP. (See *"Hop Limit"*.)	X	X
include	Include specified administrative groups. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X
metric	Assigns a metric to this LSP. (See *"LSP Metric"*.)	X	
mtu	Maximum transmission unit (MTU) for the path.	X	X
no-cspf	LSP does *not* use constrained shortest path first (CSPF) algorithm. This parameter *must* be specified for explicit path LSPs. (See *"Disabling CSPF"*.)	X	X
no-decrement-ttl	TTL field of IP packet is decremented only when exiting LSP. The entire LSP appears as a single hop to IP traffic. (See *"Disabling TTL Decrementing"*.)	X	X
no-record-route	Disables recording of path route information by LSP. (See *"Disabling Path Route Recording"*.)	X	X
policy	Specifies the MPLS policy to be applied. (See *"Policies"*.)	X	X
preference	Assigns a preference value to this LSP. (See *"Preference"*.)	X	X
primary	Specifies the name of the primary explicit path.	X	
retry-interval	Number of seconds the ingress LSR waits to try to connect to the egress LSR over the primary path. Default is 15 seconds. (See *"Connection Retries"*.)	X	X
retry-limit	Number of times the ingress LSR tries to connect to the egress LSR over the primary path. Default is 5000 times. (See *"Connection Retries"*.)	X	X
secondary	Specifies the name of the secondary explicit path.	X	
standby	Sets the secondary path in standby state. Disabled by default. (See *"Standby"*.)	X	X
to	Address of the egress router.	X	

Refer to the **mpls create label-switched-path** and **mpls set label-switched-path** commands in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for more information on the above parameters.

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See *"Dynamic L3 LSP Configuration Example"* for details on how to configure a dynamic LSP on the RS.

Adaptive LSP

An LSP can be rerouted if the explicit path is reconfigured or unable to connect. When an LSP is rerouting, the existing path is torn down even if the new optimized route is not yet set up for traffic. Also, transit LSRs can allocate the same amounts of bandwidth to both the old and new paths for the same LSP; this can cause over-allocation of available bandwidth on some links.

To counter these problems, you can configure an LSP or an explicit path to be **`adaptive`**. An adaptive LSP or explicit path retains its resources and continues to carry traffic until the new LSP or path is established. An adaptive LSP or explicit path is torn down only when the new route is successfully set up for traffic. Note that if you specify an LSP to be adaptive, all primary and secondary paths of the LSP are adaptive; the primary and secondary paths share bandwidth on common links. If you specify a primary or secondary path to be adaptive, only that path will be adaptive.

Bandwidth

You can use the **`bps`** parameter to specify the bandwidth, in bits, to be reserved with RSVP for this LSP. (The default bandwidth value is 0.) If you specify a bandwidth, transit routers will reserve outbound link capacity for the LSP. LSP setup may fail if there is a failure in bandwidth reservation.

CoS Value

A class of service (CoS) value places traffic into a transmission priority queue. For packets entering an LSP, the ingress LSR can place a specific CoS value into the MPLS header. This CoS value enables all packets that enter the LSP to receive the same class of service, as all LSRs in the LSP will use the CoS set by the ingress LSR. The MPLS header and the CoS value are removed at the egress LSR.

You can assign the CoS value to be set by the ingress LSR by specifying the **`class-of-service`** parameter when configuring the LSP. If you do not specify this parameter, the CoS value placed in the MPLS header is the value that corresponds to the internal priority queue used to buffer the packet on the ingress LSR.

Hop Limit

The hop limit is the maximum number of hops, including the ingress and egress routers, allowed in the LSP. A hop limit of 2 includes only the ingress and egress routers. The default hop limit is 255, which you can change with the **`hop-limit`** parameter.

LSP Metric

Assigning a metric to LSPs forces traffic to prefer certain LSPs over other LSPs, to prefer LSPs over IGP paths, or to load share among LSPs or among LSPs and IGP paths. For example, if there are two or more LSPs to the same egress router, the LSP with the lowest metric value is the preferred path. If the metric value is the same for multiple LSPs to the same egress router, the traffic load is shared among the LSPs.

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If you are using IGP shortcuts, the LSP metric value can be added to other IGP metrics to determine the total cost of the path. IGP path and LSP metric values can be compared to determine the preferred path. For more information about using LSPs as IGP shortcuts, see Section 17.7.3, *"IGP Shortcuts."*

If an LSP exists between two BGP peers, the LSP metric represents to downstream BGP neighbors a cost value that does not change even if the LSP is rerouted.

Disabling CSPF

The **`no-cspf`** parameter disables constrained path LSP computations by the ingress LSR and must be specified when configuring an explicit path LSP. This parameter must not be specified with constrained shortest path first (CSPF) configurations; for an explanation of CSPF and configuration examples, see Section 17.7, *"Traffic Engineering."*

Disabling TTL Decrementing

With normal decrementing, the (time-to-live) TTL field in an IP packet header is decremented by 1 on each LSR in the LSP. With the **`no-decrement-ttl`** parameter, the IP packet's TTL field is only decremented by 1 at the egress router when the entire LSP is traversed, thus making the whole LSP appear as one hop. The **`no-decrement-ttl`** parameter can be applied to RSVP-signaled LSPs only. Note that the MPLS label has its own TTL that is decremented by 1 for each hop in the LSP. When the label is popped at the PHP router, the label's TTL value is not written to the IP packet's TTL and the IP packet's TTL is decremented by 1 at the egress LSR.

Disabling Path Route Recording

By default, RSVP-signaled LSPs on RS routers record path route information. While this information may be useful for troubleshooting, this function must be supported on all transit routers. Specify the **`no-record-route`** option to disable the recording.

Preference

The default preference value for an LSP is 7, which, with the exception of direct routes, is more preferred than all learned routes. Where there are multiple LSPs between the same source and destination, you can assign a different preference value to an LSP. A smaller value signifies a more desirable path.

Connection Retries

The ingress LSR tries to connect to the egress router over the primary path at 15-second intervals for up to 5000 attempts. You can change the intervals at which connections are attempted with the **`retry-interval`** parameter or change the maximum number of attempts with the **`retry-limit`** parameter. If the number of attempts by the ingress LSR to connect to the egress router exceeds the **`retry-limit`** parameter, you will need to restart the primary path.

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Standby

The secondary path is an alternate path to a destination and is only used if the primary path can no longer reach the destination. If the LSP switches from the primary to the secondary path, it will revert back to the primary when it becomes available. The switch from the primary to the secondary path can take awhile as timeouts and retries need to be exhausted. You can specify that the secondary path be placed into a "hot" standby state to allow faster cutover from the primary to the secondary path in the event of problems with link connectivity. Specify the **standby** parameter when configuring the secondary path. Note that if paths are placed into hot standby state, all LSRs in the LSP must maintain this state information.

Policies

On the RS, you can optionally create and apply a *policy* to specify the type of traffic allowed on the path. On the RS, a policy is a definition of the type of traffic to which a particular router feature is applied. For example, you can create policies that define traffic from a particular source address to a particular destination address, or traffic of a certain protocol type.

For MPLS, you can create a policy that defines traffic characteristics such as source/destination IP addresses and netmask values, source/destination MAC addresses, VLAN ID, 802.1p priority, and protocol type. You can then apply the policy to an LSP. Only the labeled packets that meet the requirements of the policy are allowed to travel on that LSP. For example, you can define a policy that allows only labeled packets with source IP addresses in the 100.1.1.0/24 network to traverse an LSP.

On the RS, use the **mpls create policy** command to create policies that you can apply to LSPs. For example, the following command creates a policy that will allow only labeled traffic with the source IP address 100.1.1.0/24:

```
mpls create policy allow_subnet_100 src-ipaddr-mask 100.1.1.0/24
```

You can then use the **mpls set static-path** or **mpls set label-switched-path** commands to apply the policy to a previously-created LSP.

```
mpls set static-path to_SanJose policy allow_subnet_100
```

Note that an MPLS policy affects the traffic that is forwarded on an LSP. If you want to restrict the *establishment* of LSPs by restricting the label requests and label bindings that are distributed, use LDP filters. For more information, see Section 17.4.6, *"Using LDP Filters."*

Dynamic L3 LSP Configuration Example

Figure 17-9 shows a network where RS router R5 is the ingress router for a dynamic LSP to the egress router R7. The LSP configuration consists of two different path designations: the primary path is an explicit path from R5 to R7, while the secondary path is an explicit path that follows specific hops from R5 to R6 and then to R7. The secondary path also

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operates in standby mode. Both paths are configured to be adaptive; that is, during route recalculation, the LSP waits until the new optimized route is set up before tearing down the previous LSP. In this example, RSVP is the signaling protocol used (LDP can also be used, as traffic engineering is not being utilized).

Additionally, a dynamic LSP will be configured from RS router R5 to the router JN1 and another from R6 to R7. These LSPs are also configured to be adaptive.

OSPF is the routing protocol that is used on all RS routers.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

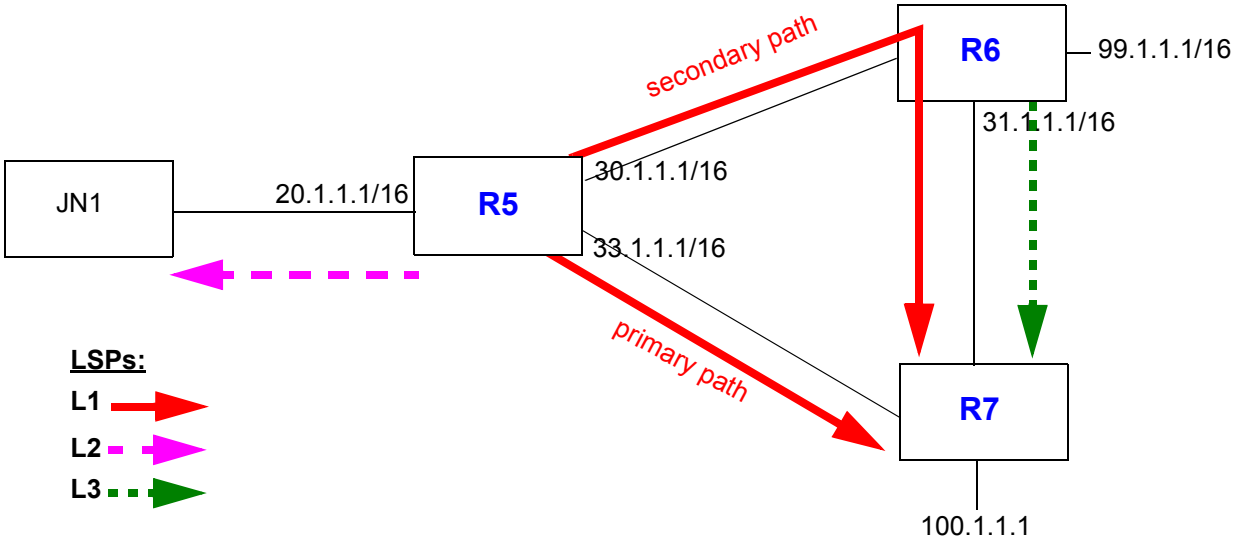

Figure 17-9 Dynamic L3 LSP paths

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The following is the configuration for router R5:

```
! Create interfaces
interface create ip 30net address-netmask 30.1.1.1/16 port et.1.2
interface create ip 33net address-netmask 33.1.1.1/16 port et.1.5
interface create ip 20net address-netmask 20.1.1.1/16 port et.5.1
interface add ip lo0 address-netmask 98.1.1.1/16

! Configure router
ip-router global set autonomous-system 64977
ip-router global set router-id 98.1.1.1

! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start

! Enable MPLS on all interfaces
mpls add interface all

! Create explicit path 57 (primary path to 100.1.1.1)
mpls create path 57

! Create explicit path 567 with 3 hops (secondary path to 100.1.1.1)
mpls create path 567 num-hops 3
mpls set path 567 hop-num 1 ip-addr 30.1.1.1
mpls set path 567 hop-num 2 ip-addr 30.1.1.2
mpls set path 567 hop-num 3 ip-addr 31.1.1.2

! Create dynamic LSP L1 to egress router 100.1.1.1 w/ primary, secondary paths
mpls create label-switched-path L1 to 100.1.1.1 no-cspf
mpls set label-switched-path L1 primary 57 adaptive
mpls set label-switched-path L1 secondary 567 adaptive standby

! Create dynamic LSP L2 to egress router 20.1.1.2
mpls create label-switched-path L2 to 20.1.1.2 adaptive no-cspf

! Start MPLS on router R5
mpls start

! Configure RSVP
rsvp add interface all
rsvp start
```


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The following is the configuration for router R6:

```
! Create interfaces
interface create ip 30net address-netmask 30.1.1.2/16 port et.1.2
interface create ip 31net address-netmask 31.1.1.1/16 port et.1.3
interface create ip 99net address-netmask 99.1.1.1/16 port et.1.1
! Configure router
ip-router global set router-id 99.1.1.1
! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start
! Enable MPLS on all interfaces
mpls add interface all
! Create dynamic LSP L3 to egress router 100.1.1.1
mpls create label-switched-path L3 to 100.1.1.1 adaptive no-cspf
! Start MPLS on router R6
mpls start
! Configure RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for router R7:

```
! Create interfaces
interface create ip 33net address-netmask 33.1.1.2/16 port et.1.5
interface create ip 31net address-netmask 31.1.1.2/16 port et.1.3
interface create ip 100net address-netmask 100.1.1.1/16 port et.1.1
! Configure router
ip-router global set router-id 100.1.1.1
! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start
! Start MPLS on router R7
mpls start
! Configure RSVP
rsvp add interface all
rsvp start
```


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Dynamic and Static L3 LSP Configuration Example

In Figure 17-10, R1 is the ingress LSR for both a dynamic LSP and a static LSP. The dynamic LSP has a primary path and one secondary path. Only traffic to the 150.10.0.0/16 network is forwarded on the dynamic LSP, while only traffic to the 160.10.0.0/16 network is forwarded on the static LSP; traffic filtering is performed by defining and applying different policies to the LSPs.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

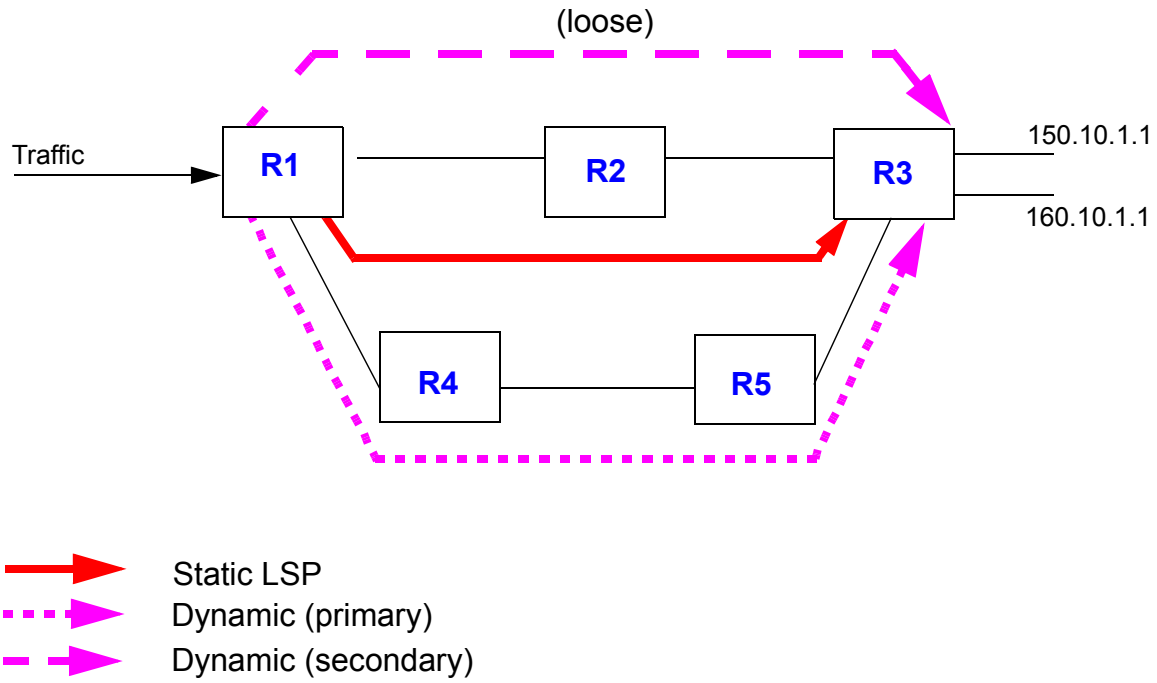

Figure 17-10 Static and dynamic L3 LSP example

In this example, RSVP is the signaling protocol used (LDP can also be used, as traffic engineering is not being utilized). OSPF is the routing protocol that is used on all RS routers.

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R1 has the following configuration:

```
! Configure interfaces
interface create ip R1R4 address-netmask 200.135.89.73/26 port gi.2.1
interface create ip R1R2 address-netmask 200.135.89.4/28 port gi.2.2
interface add ip lo0 address-netmask 1.1.1.1/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add interface R1R4 to-area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface R1R2 to-area backbone
ospf start

! Create policies
mpls create policy p1 dst-ipaddr-mask 150.10.0.0/16
mpls create policy p2 dst-ipaddr-mask 160.10.0.0/16

! Create dynamic LSP:
! Create primary path dp1
mpls create path dp1 num-hops 4
mpls set path dp1 hop 1 ip-addr 200.135.89.73 type strict
mpls set path dp1 hop 2 ip-addr 201.135.89.76 type strict
mpls set path dp1 hop 3 ip-addr 201.135.89.130 type strict
mpls set path dp1 hop 4 ip-addr 201.135.89.197 type strict
! Create secondary path dp2l (loose)
mpls create path dp2l num-hops 2
mpls set path dp2l hop 1 ip-addr 200.135.89.4 type loose
mpls set path dp2l hop 2 ip-addr 16.128.11.7 type loose
! Configure dynamic LSP d1
mpls create label-switched-path d1 to 3.3.3.3 no-cspf
mpls set label-switched-path d1 policy p1
mpls set label-switched-path d1 primary dp1 standby no-cspf
mpls set label-switched-path d1 secondary dp2l no-cspf adaptive standby

! Create static LSP s1
mpls create static-path s1 push 70,60,50 gateway 200.135.89.76 to 3.3.3.3
mpls set static-path s1 policy p2

! Start MPLS and RSVP
mpls start
rsvp start
```


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R2 has the following configuration:

```
! Configure interfaces
interface create ip R2R1 address-netmask 200.135.89.5/28 port gi.4.2
interface create ip R2R3 address-netmask 16.128.11.10/24 port gi.4.1
interface add ip lo0 address-netmask 2.2.2.2/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 2.2.2.2
ospf create area backbone
ospf add interface R2R1 to-area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface R2R3 to-area backbone
ospf start

! Configure static LSP
mpls set interface R2R1 label-map 70 pop pop-count 3 next-hop 16.128.11.7

! Start MPLS and RSVP
mpls start
rsvp start
```

R3 has the following configuration:

```
! Configure interfaces
interface create ip Net1 address-netmask 150.10.1.1/16 port et.2.8
interface create ip R3R5 address-netmask 201.135.89.197/26 port gi.6.1
interface create ip R3R2 address-netmask 16.128.11.7/24 port gi.6.2
interface add ip lo0 address-netmask 3.3.3.3/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 3.3.3.3
ospf create area backbone
ospf add interface R3R5 to-area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface R3R2 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```


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R4 has the following configuration:

```
! Configure interfaces
interface create ip R4R1 address-netmask 200.135.89.76/26 port gi.4.1
interface create ip R4R5 address-netmask 201.135.89.131/26 port gi.4.2
interface add ip lo0 address-netmask 4.4.4.4/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 4.4.4.4
ospf create area backbone
ospf add interface R4R1 to-area backbone
ospf add stub-host 4.4.4.4 to-area backbone cost 10
ospf add interface R4R5 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```

R5 has the following configuration:

```
! Configure interfaces
interface create ip R5R4 address-netmask 201.135.89.130/26 port gi.1.1
interface create ip R5R3 address-netmask 201.135.89.195/26 port gi.1.2
interface add ip lo0 address-netmask 5.5.5.5/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 5.5.5.5
ospf create area backbone
ospf add interface R5R4 to-area backbone
ospf add stub-host 5.5.5.5 to-area backbone cost 10
ospf add interface R5R3 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```


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The following is an example of the output of the **`mpls show label-switched-paths d1`** command issued at R1. Note that the state of LSP ‘d1’ is “Up” and the label value 17 is assigned to outgoing packets on this LSP.

```
R1# mpls show label-switched-paths d1
Ingress LSP:
LSPname                  To               From             State LabelIn LabelOut
d1                       3.3.3.3          1.1.1.1          Up    -       17
```

The following is an example of the output of the **`mpls show label-switched-paths d1 verbose`** command issued at R1. Note the lines that are shown in bold: the explicit path ‘dp1’ is the primary path for LSP ‘d1’ and is currently up and active, while the explicit path ‘dp21’ is the secondary path and is up but not active.

```
R1# mpls show label-switched-paths d1 verbose

    Label-Switched-Path: d1
        to: 3.3.3.32             from: 1.1.1.1
        state: Up               lsp-id: 0x9
        proto: <rsvp>           protection: primary
        setup-pri: 7            hold-pri: 0
        attributes: <POLICY PRI SEC>

        Protection-Path "dp1": <Active, Primary>
            State: Up   lsp-id: 0x1000001
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 3            ref-count: 1
            mtu: 0
            explicit-path: dp1      num-hops: 4
                200.135.89.73       - strict
                200.135.89.76       - strict
                201.135.89.130      - strict
                201.135.89.197      - strict

        Protection-Path "dp2l": <Secondary>
            State: Up   lsp-id: 0x1000002
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY ADAPTIVE NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
```


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```
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 1            ref-count: 1
            explicit-path: dp2l     num-hops: 2
                200.135.89.4        - loose
                16.128.11.7         - loose
```

If the link between R1 and R4 becomes unavailable, the configured primary path for the dynamic LSP cannot be used. The configured secondary path is then used for the LSP. A message like the following is displayed:

```
2001-04-06 16:13:24 %MPLS-I-LSPPATHSWITCH, LSP "d1" switching to Secondary Path "dp2l".
```

The secondary path ‘dp2l’ is now used for the LSP, as shown by the **`mpls show label-switched-paths d1 verbose`** command at R1. Note that the explicit path ‘dp1,’ the configured primary path, is now down and the configured secondary path ‘dp2l’ is now both up and active.

```
R1# mpls show label-switched-paths d1 verbose

    Label-Switched-Path: d1
        to: 3.3.3.3             from: 1.1.1.1
        state: Up               lsp-id: 0x9
        proto: <rsvp>           protection: secondary
        setup-pri: 7            hold-pri: 0
        attributes: <POLICY PRI SEC>

        Protection-Path "dp1": <Primary>
            State: Down         lsp-id: 0x1000001
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY RETRYING NO-CSPF>
            inherited-attributes: <>
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index:              ref-count: 1
            mtu: 0
            explicit-path: dp1      num-hops: 4
                hop: 200.135.89.73 - strict
                hop: 200.135.89.76 - strict
                hop: 201.135.89.130 - strict
                hop: 201.135.89.197 - strict

        Protection-Path "dp2l": <Active, Secondary>
            State: Up           lsp-id: 0x1000002
```


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```
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY ADAPTIVE NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 20000000           preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 1            ref-count: 1
            explicit-path: dp2l     num-hops: 2
                200.135.89.4        - loose
                16.128.11.7         - loose
```


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BGP Traffic over an LSP Configuration Example

In traditional BGP networks, BGP must be run on every router in order to provide packet forwarding. If BGP routing information is not propagated to all routers, including backbone routers, packets may not be able to be routed to their BGP destinations. You can run MPLS in a BGP network to remove BGP routing from backbone routers. Removing BGP from the backbone network provides the following benefits:

- Memory requirements for backbone routers is reduced, as they do not have to store extensive routing information
- Backbone routers do not have to perform BGP update processing, thus saving CPU utilization
- Routing tables are more stable, because backbone routers do not have to process route flaps

In Figure 17-11, R7 in AS 63498 and R9 in AS 65498 are running BGP. BGP traffic between R7 and R9 is routed through AS 64498 where OSPF is running as the IGP. Routers R3 and R6 are LSRs running MPLS and LDP, in addition to BGP.

R3 and R6 are ingress and egress LSRs for bidirectional LSPs. R1 is a transit LSR. On the LSPs, the BGP traffic is label switched, with LDP as the label signaling protocol. (RSVP can be used in MPLS networks where traffic engineering is needed.) R3 and R6 use labels that are generated for the next-hop addresses of advertised BGP routes. Packets with BGP destinations are sent across the LSPs with labels that correspond to the egress LSR that advertised the external route. Note that R1 and any other transit LSRs on the LSPs do not need to perform IP lookups nor do they need to learn BGP routing information to forward packets.

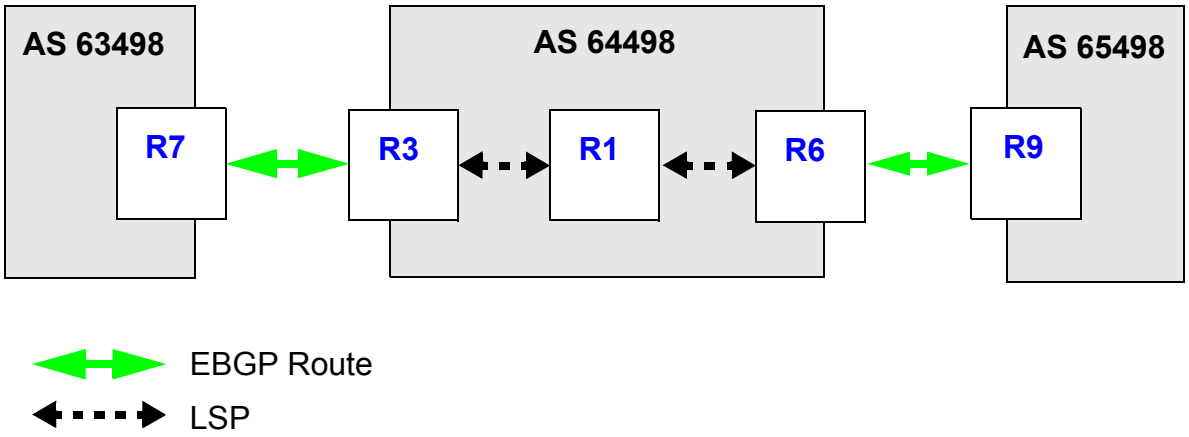

Figure 17-11 BGP traffic over an MPLS LSP

Timesaver Click on the router name (in blue) to see the corresponding configuration.

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Note By default, routes are automatically advertised between EBGP peers. However, routes are not automatically advertised between IBGP multihop peers. Therefore, in the example configuration, you need to configure routes from AS63498 and AS 65498 to be redistributed to the IBGP peers in AS 64498.

The following is the configuration for R7:

```
! Configure interfaces
interface create ip rt7-rt3 address-netmask 137.1.1.7/24 port et.1.1
interface create ip rt7-rt3.mp address-netmask 137.2.2.7/24 port et.2.7
interface add ip lo0 address-netmask 7.7.7.7/32

! Configure BGP
ip-router global set router-id 7.7.7.7
ip-router global set autonomous-system 63498
ip add route default gateway 137.2.2.3
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group to-rt3 type external autonomous-system 64498
bgp add peer-host 137.2.2.3 group to-rt3
bgp start
```


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R3 is the both the ingress LSR for the LSP to R6 and the egress LSR for the LSP from R6. The following is the configuration for R3:

```
! Configure interfaces
interface create ip rt3-rt7.mp address-netmask 137.2.2.3/24 port et.7.8
interface create ip rt3-rt1.mp address-netmask 113.2.2.3/24 port gi.3.1
interface add ip lo0 address-netmask 3.3.3.3/32

! Configure BGP
ip-router global set router-id 3.3.3.3
ip-router global set autonomous-system 64498
ip-router policy redistribute from-proto bgp source-as 63498 to-proto bgp target-as 64498
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group to-rt6 type routing autonomous-system 64498
bgp create peer-group to-rt7 type external autonomous-system 63498
bgp add peer-host 6.6.6.6 group to-rt6
bgp add peer-host 137.2.2.7 group to-rt7
bgp set peer-group to-rt6 local-address 3.3.3.3
bgp set peer-group to-rt6 next-hop-self Sets R3's address as next-hop in BGP route advertisements
bgp start

! Configure OSPF
ospf create area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface rt3-rt1.mp to-area backbone
ospf start

! Enable and start MPLS and LDP on interface to R1
mpls add interface rt3-rt1.mp
mpls start
ldp add interface rt3-rt1.mp
ldp start
```


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R1 is the transit LSR for the LSPs from R3 to R6 and from R6 to R3. The following is the configuration for R1:

```
! Configure interfaces
interface create ip rt1-rt3.mp address-netmask 113.2.2.1/24 port gi.3.2
interface create ip rt1-rt6.mp2 address-netmask 116.3.3.1/24 port gi.3.1
interface add ip lo0 address-netmask 1.1.1.1/32

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface rt1-rt3.mp to-area backbone
ospf add interface rt1-rt6.mp2 to-area backbone
ospf start

! Enable and start MPLS and LDP on interfaces to R3 and R6
mpls add interface rt1-rt6.mp2
mpls add interface rt1-rt3.mp
mpls start
ldp add interface rt1-rt3.mp
ldp add interface rt1-rt6.mp2
ldp start
```


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R6 is the both the ingress LSR for the LSP to R3 and the egress LSR for the LSP from R3.The following is the configuration for R6:

```
! Configure interfaces
interface create ip rt6-rt9 address-netmask 169.1.1.6/24 port et.7.2
interface create ip rt6-rt1.mp2 address-netmask 116.3.3.6/24 port gi.4.2

! Configure BGP
interface add ip lo0 address-netmask 6.6.6.6/32
ip-router global set router-id 6.6.6.6
ip-router global set autonomous-system 64498
ip-router policy redistribute from-proto bgp source-as 65498 to-proto bgp target-as 64498
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group bgp-to-rt9 type external autonomous-system 65498
bgp create peer-group to-rt3 type routing autonomous-system 64498
bgp add peer-host 169.1.1.9 group bgp-to-rt9
bgp add peer-host 3.3.3.3 group to-rt3
bgp set peer-group to-rt3 local-address 6.6.6.6
bgp set peer-group to-rt3 next-hop-self Sets R6's address as next-hop in BGP route advertisements
bgp start

! Configure OSPF
ospf create area backbone
ospf add stub-host 6.6.6.6 to-area backbone cost 10
ospf add interface rt6-rt1.mp2 to-area backbone
ospf start

! Enable and start MPLS and LDP on the interface to R1
mpls add interface rt6-rt1.mp2
mpls start
ldp add interface rt6-rt1.mp2
ldp start
```

The following is the configuration for R9:

```
! Configure interfaces
interface create ip rt9-rt6 address-netmask 169.1.1.9/24 port et.1.1
interface create ip rt9-32 address-netmask 92.1.1.9/24 port et.3.2
interface create ip rt9-33 address-netmask 93.1.1.9/24 port et.3.3
interface create ip rt9-34 address-netmask 94.1.1.9/24 port et.3.4
interface create ip rt9-35 address-netmask 95.1.1.9/24 port et.3.5
interface create ip rt9-36 address-netmask 96.1.1.9/24 port et.3.6
interface create ip rt9-37 address-netmask 97.1.1.9/24 port et.3.7
interface create ip rt9-38 address-netmask 98.1.1.9/24 port et.3.8
interface add ip lo0 address-netmask 9.9.9.9/32

! Configure BGP
ip-router global set router-id 9.9.9.9
ip-router global set autonomous-system 65498
ip add route default gateway 169.1.1.6
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group bgp-to-nil6 type external autonomous-system 64498
bgp add peer-host 169.1.1.6 group bgp-to-nil6
bgp start
```


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MPLS with CMTS for Multiple ISPs Configuration Example

Utilizing MPLS technology, Multiple Service Operators (MSOs) can dedicate LSPs to each supported ISP, allowing subscribers to be separated onto appropriate pipelines. Differentiating ISP traffic enables ISPs and MSOs to deliver value-added services, such as tailored service level agreements (SLAs) to each individual subscriber and improved voice-based technologies.

In the example below, an MSO supports two ISPs: AOL and AT&T. The LSP *dynamic2AOL* will carry traffic belonging to subscribers of AOL, while the LSP *dynamic3ATT* will carry traffic belonging to AT&T subscribers. The third LSP, *dynamic1MSO,* will be used by the MSO to assign IP addresses to subscriber's end devices and to provision cable modems; the MSO can also use the LSP to provide Internet services to customers who are non-subscribers of either AOL or AT&T and to provide other value-added services offered by the MSO.

Note In this example, the MSO is the sole provider for IP addressing, therefore only one DHCP server is required. The configuration for the DHCP server in a shared network environment is shown in this section.

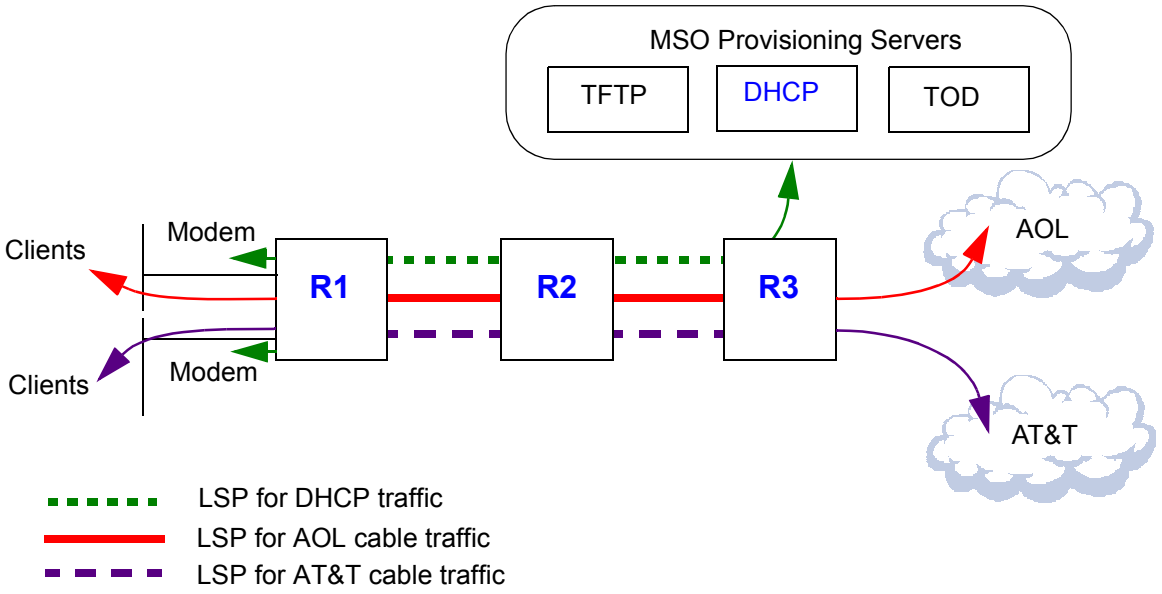

Figure 17-12 Cable modem traffic over LSP

Timesaver Click on the router name (in blue) to see the corresponding configuration.

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Note The configuration examples shown in this section are for Riverstone's DOCSIS 1.0 CMTS hardware and software. See Chapter 7, *"CMTS Configuration Guide"* for more information about configuring CMTS on RS routers.

The following is the configuration for R1:

```
! Configure CMTS
cmts set headend cm.15.1 hashed-auth-str xBFakK
cmts set uschannel cm.15.1 upstream 1-4 state on
cmts set relay-agent interface cmts giaddr 160.10.1.1

! Configure VLAN
vlan create cmts port-based
vlan add ports cm.15.1 to cmts id 200

! Configure interfaces
interface create ip R1toR2 address-netmask 210.1.1.1/16 port gi.3.2
interface create ip cmts address-netmask 160.11.1.1/16 vlan cmts
interface add ip lo0 address-netmask 1.1.1.1/16
interface add ip cmts address-netmask 160.10.1.1/16
interface add ip cmts address-netmask 160.12.1.1/16

! Configure OSPF
ip-router global set router-id 1.1.1.1
ip-router global set install-lsp-routes on
ospf create area backbone
ospf add interface R1toR2 to-area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface cmts to-area backbone
ospf start

! Configure MPLS
mpls add interface R1toR2

! Create explicit path dp1
mpls create path dp1 num-hops 3
mpls set path dp1 hop 1 ip-addr 210.1.1.1 type strict
mpls set path dp1 hop 2 ip-addr 210.1.1.2 type strict
mpls set path dp1 hop 3 ip-addr 220.1.1.1 type strict

! Create LSP for DHCP server provisioning
mpls create label-switched-path dynamic1MSO to 3.3.3.3 no-cspf
mpls set label-switched-path dynamic1MSO primary dp1
mpls create policy port67DHCP dst-port 67 dst-ipaddr-mask 150.10.0.0/16
mpls create policy MSO150 src-ipaddr-mask 150.10.0.0/16
mpls set label-switched-path dynamic1MSO policy port67DHCP
```


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```
mpls set label-switched-path dynamic1MSO policy MSO150

! Create LSP for AT&T ISP
mpls create label-switched-path dynamic3ATT to 3.3.3.3 no-cspf
mpls set label-switched-path dynamic3ATT primary dp1
mpls create policy ATT12 src-ipaddr-mask 160.12.0.0/16
mpls set label-switched-path dynamic3ATT policy ATT12

! Create LSP for AOL ISP
mpls create label-switched-path dynamic2AOL to 3.3.3.3 no-cspf
mpls create policy AOL11 src-ipaddr-mask 160.11.0.0/16
mpls set label-switched-path dynamic2AOL primary dp1
mpls set label-switched-path dynamic2AOL policy AOL11

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface R1toR2
rsvp start
ip helper-address interface cmts 150.10.1.2
```

The following is the configuration for R2:

```
! Configure interfaces
interface create ip R2toR1 address-netmask 210.1.1.2/16 port gi.15.2
interface create ip R2toR3 address-netmask 220.1.1.2/16 port gi.15.1
interface add ip lo0 address-netmask 2.2.2.2/16

! Configure OSPF
ip-router global set install-lsp-routes on
ospf create area backbone
ospf add interface R2toR1 to-area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface R2toR3 to-area backbone
ospf start

! Configure MPLS
mpls add interface R2toR1
mpls add interface R2toR3
mpls start

! Configure RSVP
rsvp add interface R2toR1
```


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```
rsvp add interface R2toR3
rsvp start
```

The following is the configuration for R3:

```
! Configure VLAN
vlan create MSOPROVISIONING port-based id 100
vlan add ports et.3.1 to MSOPROVISIONING

! Configure interfaces
interface create ip R3toR2 address-netmask 220.1.1.1/16 port gi.12.1
interface create ip MSOPROVISIONING address-netmask 150.10.1.13/16 vlan MSOPROVISIONING
interface add ip lo0 address-netmask 3.3.3.3/16

! Configure OSPF
ip-router global set router-id 3.3.3.3
ip-router global set install-lsp-routes on
ospf create area backbone
ospf add interface R3toR2 to-area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface MSOPROVISIONING to-area backbone
ospf start

! Configure MPLS
mpls add interface R3toR2

! Create explicit path dp.1.2
mpls create path dp1.2 num-hops 3
mpls set path dp1.2 hop 1 ip-addr 220.1.1.1 type strict
mpls set path dp1.2 hop 2 ip-addr 220.1.1.2 type strict
mpls set path dp1.2 hop 3 ip-addr 210.1.1.1 type strict

! Create LSP for DHCP server provisioning
mpls create label-switched-path dynamic1.2MSO to 1.1.1.1 no-cspf
mpls set label-switched-path dynamic1.2MSO primary dp1.2
mpls create policy MSOMANAGEMENT.2 dst-ipaddr-mask 160.10.0.0/16
mpls create policy MSOCPEDHCP68 src-port 68 src-ipaddr-mask 150.10.0.0/16
mpls create policy MSOCPEDHCP67 src-port 67 src-ipaddr-mask 150.10.0.0/16
mpls set label-switched-path dynamic1.2MSO policy MSOMANAGEMENT.2
mpls set label-switched-path dynamic1.2MSO policy MSOCPEDHCP68
mpls set label-switched-path dynamic1.2MSO policy MSOCPEDHCP67

! Create LSP for AOL ISP
mpls create label-switched-path dynamic2.2AOL to 1.1.1.1 no-cspf
mpls create policy AOL11.2 dst-ipaddr-mask 160.11.0.0/16
```


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```
mpls set label-switched-path dynamic2.2AOL primary dp1.2
mpls set label-switched-path dynamic2.2AOL policy AOL11.2

! Create LSP for AT&T ISP
mpls create label-switched-path dynamic3.2ATT to 1.1.1.1 no-cspf
mpls create policy ATT12.2 dst-ipaddr-mask 160.12.0.0/16
mpls set label-switched-path dynamic3.2ATT primary dp1.2
mpls set label-switched-path dynamic3.2ATT policy ATT12.2

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface R3toR2
rsvp start
```

DHCP Configuration

Note A shared network DHCP configuration will be necessary to accommodate the example shown in Figure 17-12, because multiple subnets exist on a single interface. It is also recommended that subscriber devices be configured to use the same gateway address as cable modems; this will provide improved network utilization when implementing a shared network architecture.

The following example shows the configuration of the DHCP server shown in Figure 17-12 to support the shared network environment for the Internet Software Consortium (ISC):

```
# Global Parameters

default-lease-time 2592000;
max-lease-time 2592000;

# Supported Subnets


# This is the range of IPs that are
# dynamically handed out to the requesting
# cablemodems.
subnet 160.10.0.0 netmask 255.255.0.0{
range 160.10.1.100 160.10.2.254;
filename "harvey1.cfg";
```


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```
option routers 160.10.1.1;
option time-servers 150.10.1.2;
option ntp-servers 150.10.1.2;
next-server 150.10.1.2;
option time-offset -25200;

}


shared-network MULTIPLE-ISP {

             #AOL
             #ip-range 160.11.1.10-160.11.5.254
             subnet 160.11.0.0 netmask 255.255.0.0 {
             option routers 160.10.1.1;
             option domain-name-servers xxx.xxx.xxx.xxx;
             option domain-name "AOL.com"
             }

                    host AOL1      { hardware ethernet 00:e0:6f:02:f5:09;
                                     fixed-address 160.11.1.10;
             }


             #ATT
             #ip-range 160.12.1.10-160.12.5.254
             subnet 160.12.0.0 netmask 255.255.0.0 {
             option routers 160.10.1.1;
             option domain-name-servers xxx.xxx.xxx.xxx;
             option domain-name "ATT.com"
             }
                    host ATT      { hardware ethernet 00:a0:7f:32:f4:09;
                                    fixed-address 160.12.1.10;
             }

}
```

Configuring Shared Networks with Cisco Network Registrar

Network Registrar supports multiple logical subnets on the same physical network segment. If you have several logical subnets on the same physical network (for example, 192.168.1 and 192.168.46), you might want to configure DHCP so that it offers addresses from both pools. By pooling addresses, you can combine two class C networks, or a Class B and Class C network.

To join two logical subnets, first create two scopes, then select one to be the primary and the other to be the secondary. Any client on the physical network will then obtain a lease from either scope on a round-robin basis (as long as the client does not have a reservation or previous lease information).

1. Create a second scope that you want to make a secondary scope.

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2. Open the properties for the scope.
3. Click the Advanced tab.
4. Select the Make this scope a secondary check box.
5. In the Primary scope field, select the scope that you want to designate as the primary. (This must be one of the other scopes for the server.)
6. Click OK.
7. Reload the DHCP server.

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17.6 CONFIGURING L2 TUNNELS

Riverstone's layer-2 (L2) MPLS implementation supports the encapsulation and transport of L2 Protocol Data Units (PDUs) across an MPLS network, as described in the Martini Internet-Draft. This feature allows you to use MPLS labels, instead of network layer encapsulation, to tunnel L2 frames across a backbone MPLS network. For metro service providers, this has many important benefits:

- Scalability of 802.1q and IP VPN services. With 802.1q VLANs, the total number of VLANs in the entire network is limited to 4,096. With IP VPNs, layer-2 tunnel protocol (L2TP) tunnels that carry traffic across the MPLS network must be manually configured with a pair of IP addresses assigned to each tunnel. With MPLS, packets to be sent through the L2 tunnel can be considered as a single FEC. Transit LSRs only need to look at the top label to switch the labeled packet across the MPLS network.
- L2 tunnels across backbone networks can be added as virtual interfaces to VLANs, allowing transparent bridging across the backbone. Customer network information, such as MAC addresses and VLAN IDs, is not exposed to the backbone network since only the outer MPLS label is examined by each router in the tunnel.
- Many end-to-end customer-specific or VLAN-specific *virtual circuits* can be bundled into a small number of L2 tunnels that run through the backbone. Traffic on each virtual circuit is isolated from each other, with the same level of security as a frame relay or ATM virtual circuit.

The RS supports two basic types of virtual circuit labels:

- *Static* labels require that you configure all routers and all labels in the path. MPLS must be enabled. No signaling protocol is used, so you do not need to enable RSVP or LDP.
- *Dynamic* labels use LDP signaling on the ingress and egress LSRs to specify the FEC-to-label mapping for the virtual circuit. You can use either RSVP or LDP signaling within the tunnel LSP.

Note The RS supports the transport of Ethernet frames only with MPLS labels.

17.6.1 Configuring L2 Static Labels

With L2 static labels, *each* router in the path must be configured with static forwarding information. No signaling protocol is used. MPLS must be enabled on all routers, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."*

Note Because each L2 LSP is *unidirectional*, you need to configure one LSP in each direction to provide a *bidirectional* pipe. You do not need to configure the *same* LSRs in each path.

For an L2 static LSP, the following criteria can be considered for the FEC-to-label binding:

- VLAN ID and source and/or destination MAC address
- VLAN ID and 802.1p priority

You configure a *policy* on the ingress LSR so that only frames that meet certain criteria, such as a specific VLAN ID and source MAC address, are mapped to an FEC for forwarding on the LSP.

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This section describes how to configure the ingress, transit, and egress LSRs for a static L2 LSP, as shown in Figure 17-13.

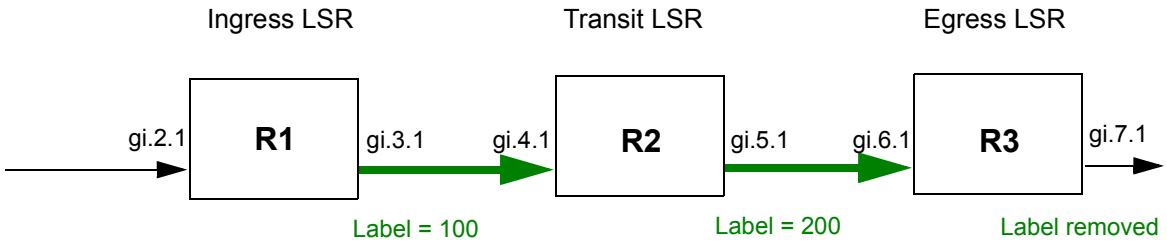

Figure 17-13 Static L2 path (unidirectional)

Ingress LSR Configuration

To configure an L2 static path on R1:

1. Use the **mpls create l2-policy** command to specify which L2 frames will be subject to label mapping and forwarding. In addition to specifying the incoming and outgoing ports, you can also specify the following:
   - destination MAC address or mask
   - source MAC address or mask
   - VLAN ID
   - 802.1p priority of the incoming packet
2. Use the **mpls create l2-static-path** command to configure the next hop MAC address and one or more label values to be added (*pushed*) onto the top of the label stack.
3. Use the **mpls set l2-static-path** command to apply the L2 policy to the L2 static path.

For example, the following commands create the static path TO-R3 for frames with the source MAC address 000000:01e000 received on port gi.2.1.

```
! Create policy P1 for frames with source MAC 000000:01e000 and VLAN ID 1
mpls create l2-policy P1 dst-mac any src-mac 000000:01e000 vlan 1 in-port-list gi.2.1
out-port-list gi.3.1

! Create static path TO-R3 to MAC a000285:057900 with label '100' pushed onto the top of the label stack
mpls create l2-static-path TO-R3 next-hop-mac 000285:057900 push 100

! Apply L2 policy P1 to L2 static path TO-R3
mpls set l2-static-path TO-R3 policy P1
```


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Transit LSR Configuration

In a static L2 LSP, transit LSRs can change (*swap*) the label value at the top of the label stack. Use the **mpls set portlist** command to configure the static L2 LSP on the RS. When configuring the static L2 LSP on the transit LSR, you specify:

- the incoming port(s)
- the outgoing port(s)
- the next-hop MAC address
- the incoming label value and one of the following actions to be taken on the label (the *label map*):
  - swap the incoming label with a specified outgoing label value
  - pop the top value on the label stack
  - push a new label value on the top of the label stack

For example, the following command on a transit LSR looks at packets arriving on the port gi.4.1. Packets that have a label value of 100 have their labels replaced by the value 200 before they are sent to the next-hop MAC address 00e063:3738ce.

```
mpls set portlist label-map 100 swap 200 next-hop-mac 00e063:3738ce in-port-list gi.4.1
out-port gi.5.1
```

Egress LSR Configuration

In a static L2 LSP, the egress LSR removes (pops) the label value at the top of the label stack and then forwards the packet to its final destination. Use the **mpls set portlist** command to configure the static L2 LSP on the RS. When configuring the static L2 LSP on the egress LSR, you specify:

- the incoming port(s)
- the incoming label value to be popped from the label stack (normally, this would be the *only* label in the stack, as this is the egress router)

For example, the following command on an egress LSR looks at packets arriving on port gi.6.1. Packets that have a label value of 200 have their label popped before they are sent to the destination VLAN (as determined by the 802.1q header or the VLAN ID associated with the incoming port):

```
mpls set portlist in-port-list gi.6.1 end-of-l2-tunnel-label 200
```

As mentioned previously, you need to configure an L2 LSP in each direction to allow for bi-directional traffic flow. Thus, the static LSPs will logically appear as shown in Figure 17-14. The configurations of routers R1, R2, and R3 for both paths are shown below.

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Timesaver Click on the router name (in blue) to see the corresponding configuration

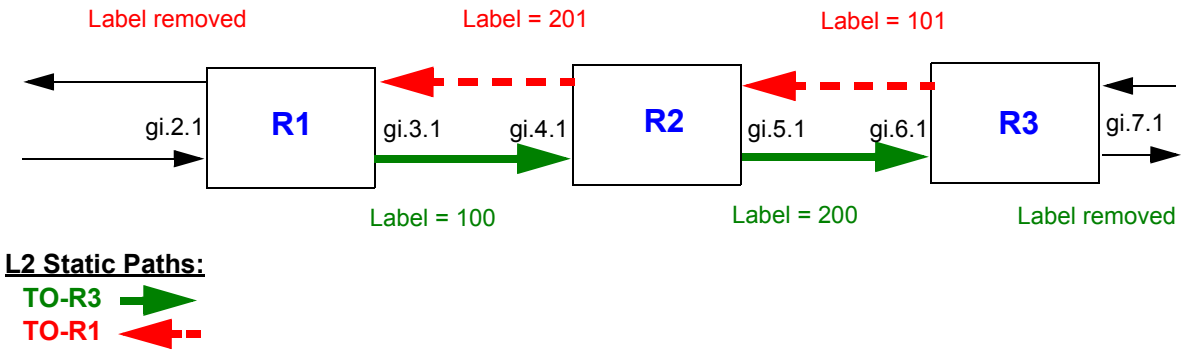

Figure 17-14 Static L2 paths (bi-directional)

Router R1 has the following configuration:

```
! Create L2 static path TO-R3
mpls create l2-policy P1 dst-mac any src-mac 000000:01e000 vlan 1 in-port-list gi.2.1
out-port-list gi.3.1
mpls create l2-static-path TO-R3 next-hop-mac 000285:057900 push 100
mpls set l2-static-path TO-R3 policy P1

! Configure egress LER for L2 static path TO-R1
mpls set portlist in-port-list gi.3.1 end-of-l2-tunnel-label 201

! Start MPLS on this router
mpls start
```

Router R2 has the following configuration:

```
! Configure L2 static path TO-R3
mpls set portlist label-map 100 swap 200 next-hop-mac 00e063:3738ce in-port-list gi.4.1
out-port gi.5.1

! Configure L2 static path TO-R1
mpls set portlist label-map 101 swap 201 next-hop-mac 00e063:110012 in-port-list gi.5.1
out-port gi.4.1

! Start MPLS on this router
mpls start
```


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Router R3 has the following configuration:

```
! Create L2 static path TO-R1
mpls create l2-policy P2 src-mac any dst-mac 000000:01e000 vlan 1 in-port-list gi.7.1
out-port-list gi.6.1
mpls create l2-static-path TO-R1 next-hop-mac 000285:057900 push 101
mpls set l2-static-path TO-R1 policy P2

! Configure egress LER for L2 static path TO-R3
mpls set portlist in-port-list gi.6.1 end-of-l2-tunnel-label 200

! Start MPLS on this router
mpls start
```


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17.6.2 Configuring Dynamic L2 Labels

In Figure 17-15, layer-2 frames are received at the ingress LSR R1, then transmitted to the egress LSR R2 across an MPLS network through a *tunnel LSP*. At the ingress LSR, a *virtual circuit* (*VC*) *label* is added to the L2 frame. The VC label is used to inform the egress LSR how to treat the received packet and the interface on which the frame is to be output. When R1 sends the L2 frame to R2, a *tunnel label* is pushed onto the MPLS label stack. As the packet traverses through the MPLS network, additional labels can be pushed onto and popped off the label stack. A number of L2 VCs can be carried in this way across a single tunnel LSP.

Note that the process of transporting L2 frames across an MPLS network is unidirectional; you will need to repeat the configuration in the reverse direction to provide bidirectional operation. You must configure the same VC identifiers (for example, VLAN IDs) for each direction of a virtual circuit.

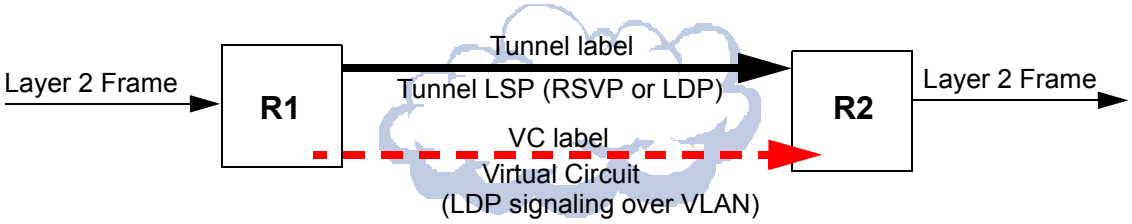

Figure 17-15 Transport of layer 2 frames across an MPLS network

Virtual Circuit Signaling

For dynamic label assignments, the VC label is distributed using LDP in downstream unsolicited mode. A remote LDP connection must be established between the ingress and egress LSRs. You configure VLANs to carry the signaling necessary to establish the LDP connection. In this section, these VLANs are referred to as *LDP-signaling VLANs*.

Tunnel LSP Signaling

Either RSVP or LDP can be used to assign and distribute the tunnel labels used within the tunnel LSP. If you use RSVP for signaling in the tunnel LSP, you need to configure LSPs with the **`mpls create`** and/or **`mpls set`** commands. If you use LDP for signaling in the tunnel LSP, you do not need to configure LSPs with the **`mpls`** commands; however, you need to enable and start MPLS on tunnel LSRs.

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Note The MTU size for MPLS ports must be at least 22 bytes more than the MTU size of incoming non-MPLS traffic; additional bytes are required for multiple labels. The default maximum transmission unit (MTU) size for non-MPLS ports on the RS is 1522 bytes. The default MTU size for ports on MPLS-enabled line cards on the RS is 1568 bytes, which allows for multiple MPLS labels).

The MPLS network must be configured with an MTU that is large enough to transport the maximum size frame that will be transported in the tunnel LSP (this can be at least 12 bytes more than the largest frame size). If an MPLS packet exceeds the tunnel MTU, it will be dropped. If an egress LSR receives a packet that exceeds the MTU of the destination L2 interface, the packet will be dropped.

FEC-Label Bindings

On the RS, the following can be used to identify the FEC-to-label binding for a virtual circuit:

- VLAN ID assigned to a customer by a service provider
- incoming port
- incoming port and the customer-specific VLAN ID assigned by the customer

This section includes example configurations for each type of FEC-to-label binding.

Ingress and Egress LSR Configuration for L2 Dynamic Labels

On the ingress and egress LSRs, configure the following:

1. Configure the L2 FEC.
   - If you are using the VLAN ID as the FEC, create the VLAN with the **`vlan create`** and **`vlan add ports`** commands.
   - If you are using the incoming port as the FEC, use the **`ldp map ports`** command to map the port to a logical customer ID number.

Note The ports that are mapped to a single customer ID number must be either all trunk ports or all access ports.

A port cannot be mapped to more than one customer ID number.

   - If you are using a combination of customer VLAN ID and incoming port as the FEC, create the VLAN with the **`vlan create`** and **`vlan add ports`** commands and use the **`ldp map ports`** command to map the port to a logical customer ID number.
2. Advertise the FEC-to-label mapping via LDP to the remote peers. Enable and start LDP.
   - Specify the remote LDP peer with the **`ldp add remote-peer`** command. Specify the router ID of the remote LDP peer, which must be one of the loopback addresses of the remote router.

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- If you are using the VLAN ID as the FEC, specify the **vlan** option with the **ldp add l2-fec** command.
- If you are using the incoming port as the FEC, specify the **customer-id** option with the **ldp add l2-fec** command.
- If you are using a combination of VLAN ID and incoming port as the FEC, specify both the **vlan** and **customer-id** options with the **ldp add l2-fec** command.

3. Configure the LDP-signaling VLAN and interface. The ports at both ends of a link between two LSRs must belong to the same VLAN, i.e., the VLAN ID must be the same on both routers.

Note Ports in the LDP-signaling VLAN must be trunk ports. If "untagged" packets are to be transported on the LSP, the tunnel port must be configured as a trunk port that does not send 802.1q-tagged packets (use the **untagged** option with the **vlan make trunk-port** command).

4. Configure the tunnel LSP. If you are using RSVP for signaling in the tunnel LSP, use **mpls** commands, as described in Section 17.5, *"Configuring L3 Label Switched Paths."* If you configure more than one tunnel LSP to the same destination, you can specify the preferred LSP to be used with the **transport-lsp** option of the **ldp set l2-fec** command. You can also specify if an alternate LSP can be used. Enable and start MPLS and the signaling protocol (either LDP or RSVP) for the tunnel LSP.

Note The **transport-lsp** option of the **ldp set l2-fec** command allows you to assign a specific LSP to specific customer traffic. This provides a way to offer different LSP services to different customers.

5. Configure the IGP routing protocol, either OSPF or IS-IS.

Transit LSR Configuration for L2 Dynamic Labels

On the transit LSRs, configure the following:

1. Configure the LDP- or RSVP-signaling VLAN and interface.
2. Enable and start MPLS and the signaling protocol (either LDP or RSVP) for the tunnel LSP.
3. Configure the IGP routing protocol, either OSPF or IS-IS.

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L2 Tunneling Based on VLAN ID Configuration Examples

The FEC-to-label binding for a virtual circuit can be based on the VLAN ID assigned to a customer by a service provider. Figure 17-16 shows a customer VLAN with an ID of 100, and another customer VLAN with an ID of 200. The VLANs are mapped to VC labels that are distributed via LDP. LDP-signaling VLANs carry the signaling necessary to establish the LDP connection. For example, the ports at each end of the link between R1 and R2 are configured with VLAN ID 110, while the ports at each end of the link between R2 and R3 are configured with VLAN ID 120. The tunnel LSP can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

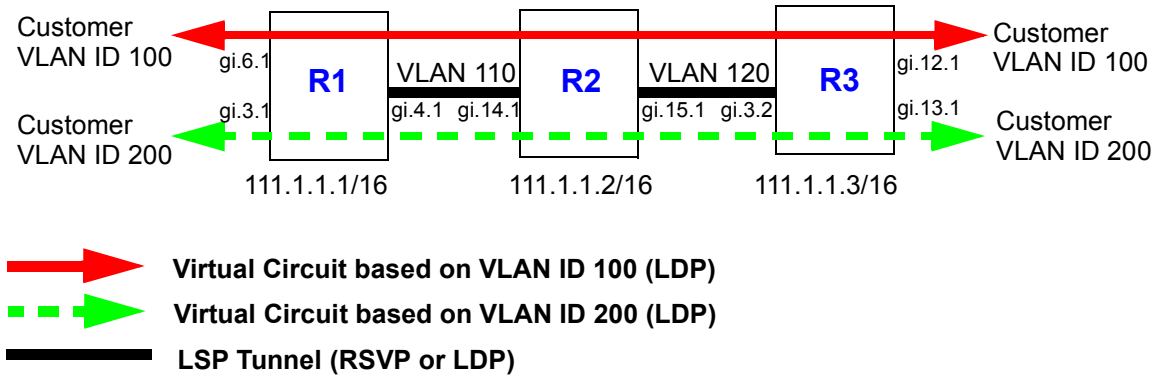

Figure 17-16 Tunneling of multiple virtual circuits based on VLAN ID

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 a trunk port
vlan make trunk-port gi.4.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.6.1, gi.4.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.3.1,gi.4.1 to cust2
```


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```
! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 sends label mapping for VLAN ID 100 to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 sends label mapping for VLAN ID 200 to R3
ldp start

! Create the LDP-signaled VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure LDP-signaling VLANs and interfaces:
vlan make trunk-port gi.14.1
vlan make trunk-port gi.15.1
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 220.1.1.1/16 vlan ldp_in3
```


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```
! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 a trunk port
vlan make trunk-port gi.3.2

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.12.1, gi.3.2 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.13.1, gi.3.2 to cust2

! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.1 sends label mapping for VLAN ID 100 to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 sends label mapping for VLAN ID 200 to R1
ldp start
```


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```
! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP  (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start
```


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Figure 17-17 shows two VLANs, with sites that are connected to routers R1, R3, and R5. The VLANs are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

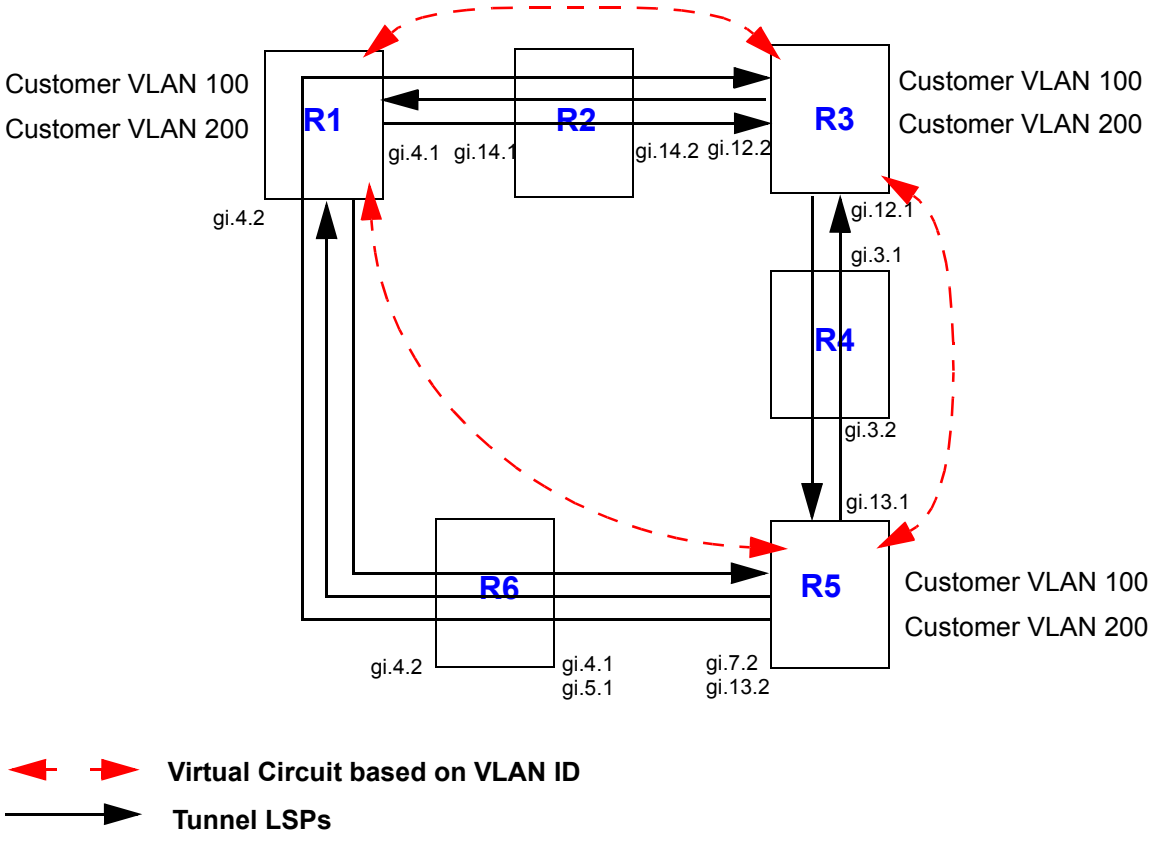

Figure 17-17 Tunneling of virtual circuits based on VLAN ID (RSVP tunnel)

Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops.

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Note If you configure more than one tunnel LSP to the same destination, you can specify the preferred LSP to be used with the **transport-lsp** option of the **ldp set l2-fec** command. You can also specify if an alternate LSP can be used. The **transport-lsp** option of the **ldp set l2-fec** command allows you to assign a specific LSP to specific customer traffic. This provides a way to offer different LSP services to different customers.

The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan make trunk-port gi.4.1
vlan make trunk-port gi.4.2
vlan create cust1 port-based id 100
vlan create cust2 port-based id 200
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based id 120
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.2 to cust1
vlan add ports gi.4.1 to ldp_in
vlan add ports gi.6.1,gi.2.2,gi.4.1 to cust1
vlan add ports gi.3.1,gi.4.1 to cust2
interface create ip to_rs2 address-netmask 200.1.1.1/16 vlan ldp_in  LDP-signaling VLAN to R2
interface create ip to_rs6 address-netmask 201.1.1.1/16 vlan ldp_in2  LDP-signaling VLAN to R6
interface create ip ip_32 address-netmask 124.2.1.1/16 port gi.3.2
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs6

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
```


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```
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3

! Configure tunnel LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure tunnel LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs6
rsvp start

! Configure LDP
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 send VLAN 100 mapping to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 send VLAN 100 mapping to R5
ldp add l2-fec vlan 200 to-peer 111.1.1.5 send VLAN 200 mapping to R3
ldp add l2-fec vlan 100 to-peer 111.1.1.5 send VLAN 200 mapping to R5
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_rs1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_rs3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
```


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```
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs3
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs3
rsvp start
```

Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and restricted to traffic destined for the 124.2.0.0/16 subnet. The following is the configuration for R3:

```
! Configure VLANs and interfaces
vlan make trunk-port gi.12.2
vlan make trunk-port gi.12.1
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan create cust1 port-based id 100
vlan create cust2 ip id 200
vlan create to_rs1_only ip id 50
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.14.1,gi.12.2 to cust1
vlan add ports gi.12.1 to ldp_if1
vlan add ports gi.12.1 to cust1
vlan add ports gi.12.2,at.3.1.0.100 to cust2
vlan add ports gi.13.2 to cust2
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4
```


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```
! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1

! Create tunnel LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp add l2-fec vlan 100 to-peer 111.1.1.1 send VLAN 100 mapping to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 send VLAN 200 mapping to R1
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.5 send VLAN 100 mapping to R5
ldp add l2-fec vlan 200 to-peer 111.1.1.5 send VLAN 200 mapping to R5
ldp start
```

R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Configure interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start
```


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```
! Configure RSVP
rsvp add interface to_rs3
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces to R4 and R6
vlan make trunk-port gi.13.1
vlan make trunk-port gi.7.2
vlan create cust1 port-based id 100
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan create cust2 ip id 200
vlan add ports gi.12.1,gi.13.2 to cust1
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
vlan add ports gi.13.1 to cust1
vlan add ports gi.6.1 to cust2
vlan add ports gi.7.2 to cust1
vlan add ports gi.7.2 to ldp_in1
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32

! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
```


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```
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start
```


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```
! Configure LDP
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 send VLAN 100 mapping to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 send VLAN 200 mapping to R3
ldp add l2-fec vlan 100 to-peer 111.1.1.1 send VLAN 100 mapping to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 send VLAN 200 mapping to R1
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure interfaces to R1 and R5
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```


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L2 Tunneling Based on Ports Configuration Examples

The FEC-to-label binding for a virtual circuit can be based on the port on which traffic arrives. One or more incoming ports are mapped to a logical customer ID number, which is then mapped to an FEC.

In Figure 17-18, ports gi.6.1 on R1 and gi.12.1 on R3 are mapped to customer ID 1. Ports gi.3.1 on R1 and gi.13.1 on R3 are mapped to customer ID 2. The customer IDs are mapped to VC labels that are distributed via LDP. You can choose to have either untagged or 802.1q tagged frames transported across the tunnel LSP; the configuration for transporting untagged packets is shown. The tunnel LSP can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP tunnel signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

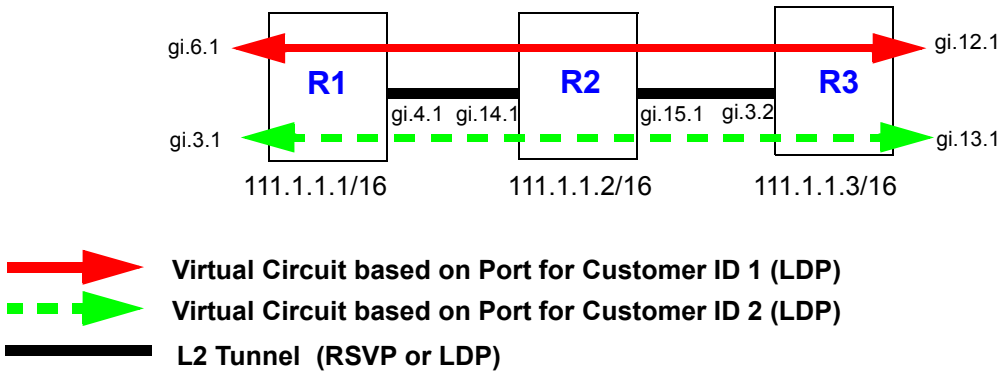

Figure 17-18 Tunneling of multiple virtual circuits based on ports (untagged frames)

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 a trunk port that does not send out 802.1q tagged frames
vlan make trunk-port gi.4.1 untagged

! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp map ports gi.6.1 customer-id 1 maps port gi.6.1 to customer-id 1
ldp map ports gi.3.1 customer-id 2 maps port gi.3.1 to customer-id 2
ldp add l2-fec customer-id 1 to-peer 111.1.1.3 sends label mapping for customer-id 1 to R3
ldp add l2-fec customer-id 2 to-peer 111.1.1.3 sends label mapping for customer-id 2 to R3
ldp start
```


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```
! Create the LDP-signaling VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure VLANs and interfaces:
vlan make trunk-port gi.14.1 untagged  configure trunk port that does not send out 802.1q tagged frames
vlan make trunk-port gi.15.1 untagged  configure trunk port that does not send out 802.1q tagged frames
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 210.1.1.1/16 vlan ldp_in3

! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start
```


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```
! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 a trunk port  that does not send out 802.1q tagged frames
vlan make trunk-port gi.3.2 untagged

! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp map ports gi.12.1 customer-id 1 maps port gi.12.1 to customer-id 1
ldp map ports gi.13.1 customer-id 2 maps port gi.13.1 to customer-id 2
ldp add l2-fec customer-id 1 to-peer 111.1.1.1 sends label mapping for customer-id 1 to R1
ldp add l2-fec customer-id 2 to-peer 111.1.1.1 sends label mapping for customer-id 2 to R1
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start
```


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```
! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP  (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start
```


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In Figure 17-19, ports gi.6.2, gi.2.1, and gi.5.1 on R1, port gi.15.1 on R3, and port gi.12.2 on R5 are mapped to customer ID 10. The customer IDs are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Note The ports that are mapped to a single customer ID number must be either all trunk ports or all access ports. The example shows configurations for transporting 802.1q traffic.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

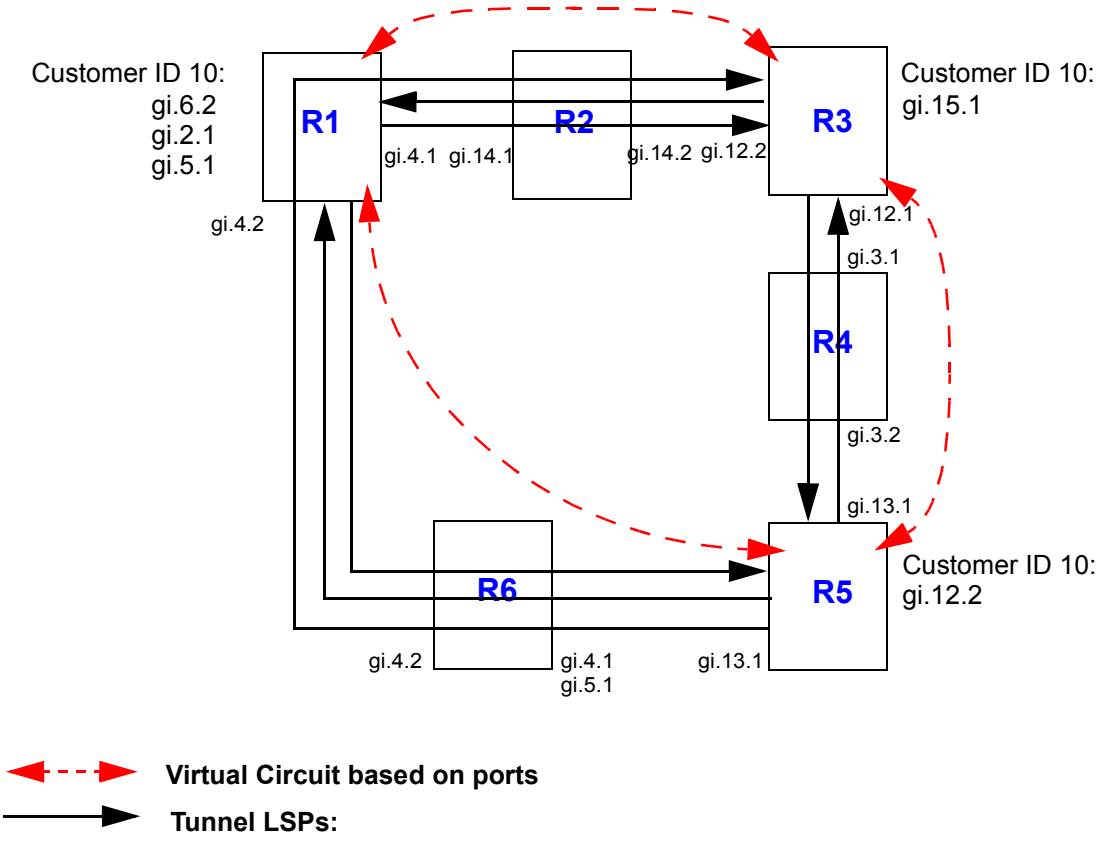

Figure 17-19 Tunneling of virtual circuits based on ports (RSVP tunnel)

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Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, and R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops. The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan make trunk-port gi.2.1 customer ports must be trunk ports for 802.1q packets
vlan make trunk-port gi.6.2  customer ports must be trunk ports for 802.1q packets
vlan make trunk-port gi.5.1  customer ports must be trunk ports for 802.1q packets
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based id 120
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.1 to ldp_in
interface create ip to_rs2_1 address-netmask 200.1.1.1/16 vlan ldp_in  LDP-signaling VLAN interface
interface create ip to_rs2_second address-netmask 201.1.1.1/16 vlan ldp_in2  LDP-signaling VLAN
interface
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2_1 to-area backbone
ospf add interface to_rs2_second to-area backbone
ospf add interface ip_to_rs3000 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2_1
mpls add interface to_rs2_second

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3

! Configure LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
```


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```
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2_1
rsvp add interface to_rs2_second
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.6.2 customer-id 10 map ports to customer-id 10
ldp map ports gi.2.1 customer-id 10
ldp map ports gi.5.1 customer-id 10
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.3 send customer-id 10 to R3
ldp add l2-fec customer-id 10 to-peer 111.1.1.5 send customer-id 10 to R5
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_RS1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_RS3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_RS1
mpls add interface to_RS3
mpls start

! Configure RSVP
rsvp add interface to_RS1
```


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```
rsvp add interface to_RS3
rsvp start
```

Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and is restricted to traffic destined for the 124.2.0.0/16 subnet. The following is the configuration for R3:

```
! Configures VLANs and interfaces
vlan make trunk-port gi.15.1  customer ports must be trunk ports for 802.1q packets
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.12.1 to ldp_if1
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf add interface ip_local_123 to-area backbone
ospf add interface to_rs38000_internet to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.15.1 customer-id 10  map port gi.15.1 to customer-id 10
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.1  send customer-id mapping to R1
ldp add remote-peer 111.1.1.5  adds R5 as LDP peer
```


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```
ldp add l2-fec customer-id 10 to-peer 111.1.1.5 send customer-id mapping to R5
ldp start
```

R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Configure VLANs and interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs3
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces to R4 and R6
vlan make trunk-port gi.12.2  customer ports must be trunk ports for 802.1q packets
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32
```


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```
! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
```


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```
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.12.2 customer-id 10  map port gi.12.2 to customer-id 10
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.1  send customer-id mapping to R1
ldp add remote-peer 111.1.1.3  adds R3 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.3  send customer-id mapping to R3
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure interfaces to R1 and R5
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```


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L2 Tunneling Based on VLAN ID and Port Configuration Examples

The FEC-to-label binding for a virtual circuit can be based on both a customer-specified VLAN ID and the port on which the traffic arrives. Each combination of VLAN ID and logical customer ID (which represents the incoming port) is mapped to a single FEC.

Figure 17-20 shows two VLANs with sites that are connected to routers R1 and R3. Port gi.6.1 on R1 and gi.12.1 on R3 provide access for the VLANs. Each VLAN ID/port combination is mapped to a VC label that is distributed via LDP. The LSP tunnel can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP tunnel signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

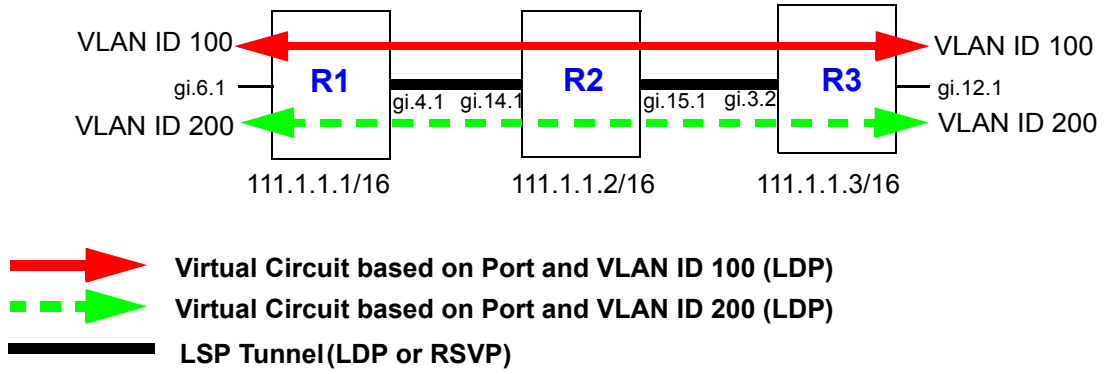

Figure 17-20 Tunneling of multiple virtual circuits based on port and VLAN ID

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 and gi.6.1 trunk ports
vlan make trunk-port gi.4.1
vlan make trunk-port gi.6.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.6.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.6.1 to cust2
```


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```
! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp map ports gi.6.1 customer-id 10 maps port gi.6.1 to customer-id 50
ldp add l2-fec customer-id 10 vlan 100 to-peer 111.1.1.3 sends label mapping for customer-id 10/VLAN ID 100 to R3
ldp add l2-fec customer-id 10 vlan 200 to-peer 111.1.1.3 sends label mapping for customer-id 10/VLAN ID 200 to R3
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure VLANs and interfaces:
vlan make trunk-port gi.14.1
vlan make trunk-port gi.15.1
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 210.1.1.1/16 vlan ldp_in3
```


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```
! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 and gi.12.1 trunk ports
vlan make trunk-port gi.3.2
vlan make trunk-port gi.12.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.12.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.12.1 to cust2
```


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```
! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp map ports gi.12.1 customer-id 10 maps port gi.12.1 to customer-id 10
ldp add l2-fec customer-id 10 vlan 100 to-peer 111.1.1.1 sends label mapping for customer-id
10/VLAN 100 to R1
ldp add l2-fec customer-id 10 vlan 200 to-peer 111.1.1.1 sends label mapping for customer-id
10/VLAN 200 to R1
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP  (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start
```


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Figure 17-21 shows two VLANs (with IDs 50 and 60) that enter R1 on port gi.2.2. VLAN 50 traffic enters R3 on port gi.15.1, while VLAN 60 traffic enters R5 on port gi.6.2. The VLAN ID/port combinations are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

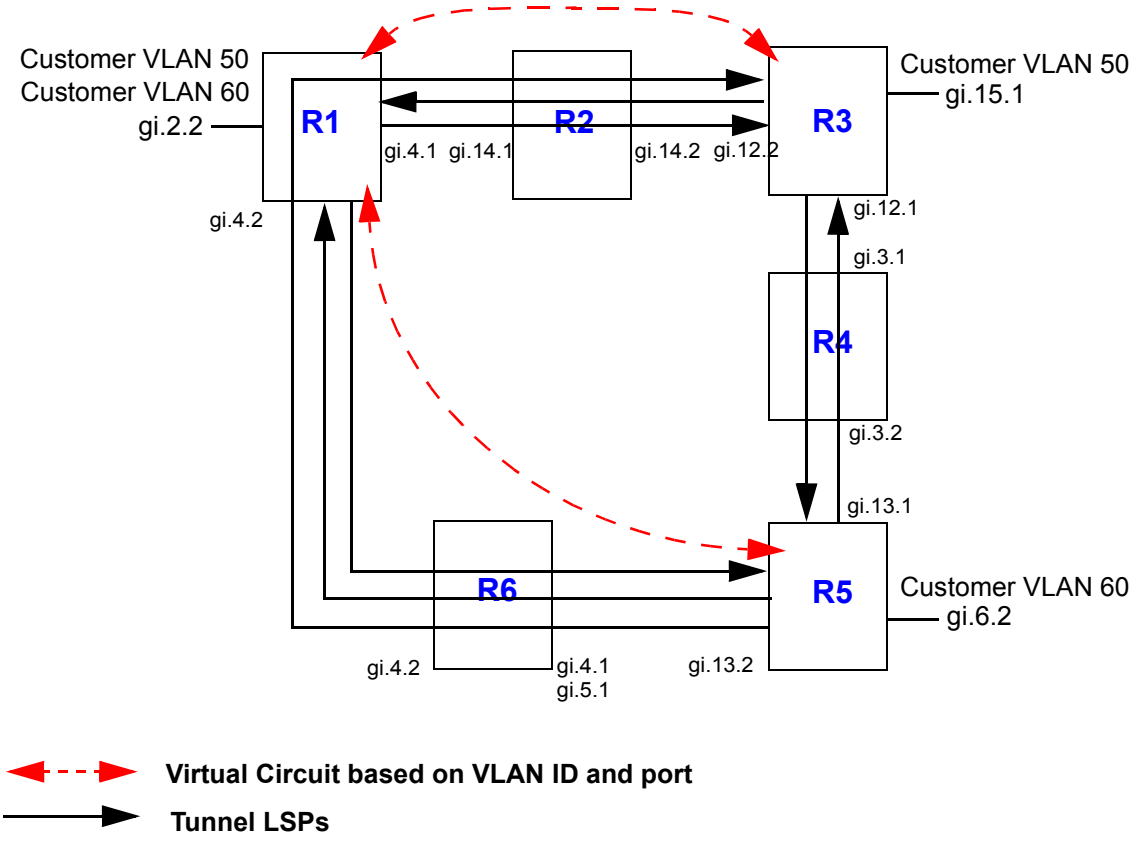

Figure 17-21 Tunneling of virtual circuits based on VLAN ID and port (RSVP tunnel)

Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops. The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based 120
vlan create to_rs3_only port-based id 50
vlan create to_rs5_only port-based id 60
```


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```
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.1 to ldp_in
vlan add ports gi.2.2 to to_rs3_only
vlan add ports gi.2.2 to to_rs5_only
interface create ip to_rs2 address-netmask 200.1.1.1/16 vlan ldp_in   LDP-signaling VLAN interface
interface create ip to_rs6 address-netmask 201.1.1.1/16 vlan ldp_in2   LDP-signaling VLAN interface
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs6

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3

! Configure LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs6
```


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```
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.2.2 customer-id 20 maps port gi.2.2 to customer-id 20
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec customer-id 20 vlan 50 to-peer 111.1.1.3 sends label mapping for customer-id 20/VLAN 50 to R3
ldp add l2-fec customer-id 20 vlan 60 to-peer 111.1.1.5 sends label mapping for customer-id 20/VLAN 60 to R5
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_RS1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_RS3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_RS1
mpls add interface to_RS3
mpls start

! Configure RSVP
rsvp add interface to_RS1
rsvp add interface to_RS3
rsvp start
```


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Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and restricted to traffic destined for the 124.2.0.0.16 subnet. The following is the configuration for R3:

```
! Create VLANs and interfaces
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan create to_rs1_only ip id 50
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.12.1 to ldp_if1
vlan add ports gi.15.1 to to_rs1_only
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.15.1 customer-id 20  maps port gi.15.1 to customer-id 20
ldp add l2-fec customer-id 20 vlan 50 to-peer 111.1.1.1  sends label mapping for customer-id 20/VLAN 50 to R1
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp start
```


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R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Create VLANs and interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs3
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan create to_rs1_only port-based id 60
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
vlan add ports gi.6.2 to to_rs1_only
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32

! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
```


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```
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
```


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```
ldp map ports gi.6.2 customer-id 20  map port gi.6.2 to customer-id 20
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add l2-fec customer-id 20 vlan 60 to-peer 111.1.1.1 sends label mapping for customer-id 20/VLAN 60 to R1
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure VLANs and interfaces
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```


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17.7 TRAFFIC ENGINEERING

One of the most important applications of MPLS is *traffic engineering*. Traffic engineering allows you to optimize the utilization of network resources and traffic performance throughout a network. Traffic engineering does not mean that the shortest path is always selected—traditional shortest path routing, as determined by interior gateway protocols (IGPs), can cause both network congestion and the overuse of certain network paths, while longer paths are under-utilized. Traffic engineering allows more efficient use of available bandwidth while avoiding congestion. Packets with the same source and destination addresses can travel completely different paths in the network.

With MPLS, explicit LSPs can provide traffic engineering. For example, you can configure two explicit paths to the same destination, with one the primary and the other the secondary path. However, explicit LSPs require you to configure the paths on the ingress router. More dynamic traffic engineering can be performed with constraint-based LSPs.

Traffic engineering requires extensions to the IGP. The RS provides extensions to OSPF and IS-IS IGPs to support traffic engineering with MPLS. Traffic engineering is disabled by default for OSPF and IS-IS on RS routers.

This section discusses some of the features of traffic engineering and provides example configurations.

17.7.1 Administrative Groups

An MPLS *administrative group*[3] designates certain link attributes that can be used to impose additional path constraints. Administrative groups can be used to contain certain traffic trunks within specific topological regions of an MPLS network. You can employ administrative groups for path setup and selection for constrained path LSPs. You can use administrative groups to:

- Apply the same policies to a set of resources that are not necessarily in the same topological area.
- Specify the relative preference of a set of resources for placement of traffic trunks.
- Restrict the placement of traffic trunks to specific sets of resources.
- Implement general include/exclude policies.
- Enforce policies that contain local traffic within specific regions of the network.
- Identify a particular set of resources.

For example, all OC-48 links in a network may be assigned to a particular administrative group. You can also assign subsets of the OC-48 links to other administrative groups.

If you use administrative groups, the names of the groups and their corresponding decimal values must be the same on all routers within the domain. You can configure up to 32 administrative groups in an MPLS domain.

You can specify one or more administrative groups to be included or excluded from an LSP computation. If you *include* any administrative groups in an LSP computation, each selected link will have at least one included group. If you *exclude* specific administrative groups in an LSP computation, each selected link cannot have any excluded groups. If you include or exclude administrative groups in an LSP computation, links that do not have an associated group are not considered. You can configure administrative group constraints for an LSP, or for a primary or secondary LSP. You can include or exclude a maximum of 16 administrative groups for an LSP, or for a primary or secondary path.

You can assign one or more administrative groups to a router interface. IGPs use administrative groups to provide information, such as IGP topology, to all routers in the domain.

If you change the administrative group for an *LSP*, the route is recalculated and the LSP may be rerouted. If you change the administrative group for an *interface*, the change affects only *new* LSPs on the interface.

3. Administrative groups are referred to as *resource classes* or *link colors* in some implementations.

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To set up administrative groups, do the following:

1. Create the administrative groups with the **`mpls create admin-group`** command. Assign each group a decimal value between 1-32. You must create identical group names and assign the same value to each group on all routers in the MPLS domain. For example:

```
mpls create admin-group sector1 group-value 1
```

2. Assign one or more groups to an interface with the **`mpls set interface`** command. This identifies the administrative groups to which the interface belongs. For example:

```
mpls set interface RS1IN admin-group sector1
```

3. Specify administrative groups to be included or excluded from an LSP computation. To include or exclude groups for an LSP, use the **`mpls create label-switched-path`** command. For example:

```
mpls create label-switched-path LSP1 include sector1
```

   To include or exclude groups for a primary or secondary LSP path, use the **`mpls set label-switched-path`** command. For example:

```
mpls set label-switched-path LSP1 primary PA include sector1
```

An example of using administrative groups is shown in Section 17.7.2, *"Constrained Shortest Path First."*

Use the **`mpls show admin-groups`** command to see the administrative groups configured on an RS. For example:

```
rs# mpls show admin-groups

       Group               Bit index
       -----               ---------
       sector1             1
```


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The **mpls show interface** command shows the interfaces configured on an RS and the administrative group, if any, that is applied to an interface. For example, in the following output the administrative group sector1 is applied to the interfaces R2R3 and R2R1b:

```
rs# mpls show interface all
Interface        State       Administrative groups
lo               Up          <none>
lo               Up          <none>
R2R3             Up          sector1
R2R1             Up          <none>
R2R1b            Up          sector1
```

17.7.2 Constrained Shortest Path First

An ingress LSR uses the information in the traffic engineering database (TED) to calculate its LSPs across the network. The constrained shortest path first (CSPF) algorithm is a modification of the OSPF and IS-IS shortest path first calculation. With CSPF, nodes and links for an LSP are accepted or rejected based on resource availability or on whether administrative group or policy constraints are met. The result is an explicit route that provides the shortest path through the network that meets certain constraints. The explicit route, comprised of a sequence of LSR addresses, is passed to the signaling protocol to deliver the path information to each LSR in the LSP.

The CSPF algorithm takes into account link-state and network state information from the TED, as well as the following LSP attributes:

- bandwidth
- hops
- administrative group
- setup and hold priority
- strict or loose explicit route

To enable CSPF on RS routers:

1. If OSPF is the IGP, enable traffic engineering extensions for OSPF with the **ospf set traffic-engineering on** command. If IS-IS is the IGP, enable traffic engineering extensions for IS-IS with the **isis set traffic-engineering enable** command.

Note Traffic engineering with OSPF as the IGP requires support for opaque LSAs (defined by RFC 2370). This support is enabled by default on the RS, but can be disabled with the **ospf set opaque-capability off** CLI command. If you are enabling traffic engineering extensions for OSPF, make sure that opaque LSA support has not been *disabled*.

2. Configure the dynamic LSP, as described in Section 17.5.3, *"Configuring an Explicit LSP."* Do *not* specify the **no-cspf** parameter with the **mpls create label-switched-path** or **mpls set label-switched-path** commands.

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Constrained Path Selection Configuration Example for OSPF Traffic Engineering

The following example illustrates constrained path selection based on an administrative group with OSPF as the IGP. The same administrative group must be configured on all routers in the LSP. In the example shown in Figure 17-22, the administrative group 'SKY' with a value of 7 is created on all LSRs and applied to the following interfaces: R1R2b on R1, R2R1b and R2R3 on R2, and R3R2 on R3. An LSP 'LSP1' is configured on R1 with R3 as the LSP destination and SKY as the administrative group. That means that even though there are two possible paths from R1 to R3, CSPF selects the path that traverses through the interfaces where the administrative group SKY is applied.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

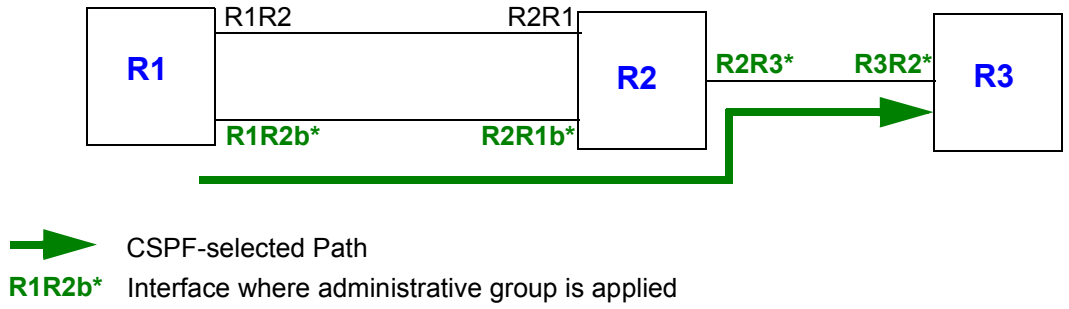

Figure 17-22 Constrained path selection by administrative group

The following is the configuration for R1:

```
! Create interfaces
interface create ip R1R2 address-netmask 16.128.11.10/24 port gi.4.1
interface create ip R1R2b address-netmask 94.9.9.10/24 port gi.3.1
interface add ip lo0 address-netmask 1.1.1.1/16

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface R1R2 to-area backbone
ospf add interface R1R2b to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start

! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R1R2b
mpls set interface R1R2b admin-group sky
```


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```
! Configure LSP with admin-group constraint (do not specify no-cspf parameter)
mpls create label-switched-path LSP1 to 3.3.3.3 include sky

!Enable and start MPLS and RSVP
mpls add interface R1R2
mpls start
rsvp add interface R1R2
rsvp add interface R1R2b
rsvp start
```

The following is the configuration for R2:

```
! Create interfaces
interface create ip R2R1 address-netmask 16.128.11.7/24 port gi.6.2
interface create ip R2R1b address-netmask 94.9.9.11/24 port gi.5.1
interface create ip R2R3 address-netmask 201.135.89.197/26 port gi.4.1
interface add ip lo0 address-netmask 2.2.2.2/16

! Configure OSPF
ip-router global set router-id 2.2.2.2
ospf create area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface R2R1 to-area backbone
ospf add interface R2R1b to-area backbone
ospf add interface R2R3 to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start

! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R2R1
mpls add interface R2R1b
mpls add interface R2R3
mpls set interface R2R1b admin-group sky
mpls set interface R2R3 admin-group sky

! Enable and start MPLS and RSVP
mpls start
rsvp add interface R2R1
rsvp add interface R2R1b
rsvp add interface R2R3
rsvp start
```


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The following is the configuration for R3:

```
! Create interfaces
interface create ip R3R2 address-netmask 201.135.89.195/26 port gi.1.2
interface add ip lo0 address-netmask 3.3.3.3/16

! Configure OSPF
ip-router global set router-id 3.3.3.3
ospf create area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface R3R2 to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start

! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R3R2
mpls set interface R3R2 admin-group sky

! Enable and start MPLS and RSVP
mpls start
rsvp add interface R3R2
rsvp start
```


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On R1, the **mpls show label-switched-paths** command with the **verbose** option displays the selected path in the **cspf-path** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group SKY is applied on the routers:

```
R1# mpls show label-switched-paths LSP1 verbose

    Label-Switched-Path: LSP1

        to: 3.3.3.3             from: 1.1.1.1
        state: Up               lsp-id: 0x8
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <>

        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 1000       retry-int: 30 sec.
            retry-count: 1000       next_retry_int: 60 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 600 sec.
            ott-index: 0            ref-count: 0
            mtu: 0
            cspf-path:   num-hops: 3
                hop: 94.9.9.10       - strict
                hop: 94.9.9.11       - strict
                hop: 201.135.89.195  - strict
           include:                  sky
           record-route:
                94.9.9.10
                94.9.9.11
                201.135.89.195
```


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Constrained Path Selection Configuration Example for IS-IS Traffic Engineering

The following examples shows the configuration of two constrained path LSPs from R1 to R4:

- LSP1 includes the administrative group ‘red’
- LSP2 includes the administrative group ‘green’ and the bandwidth constraint of 8 megabits per second

IS-IS is the IGP running on all routers in the network. IS-IS MD5 authentication is also configured.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

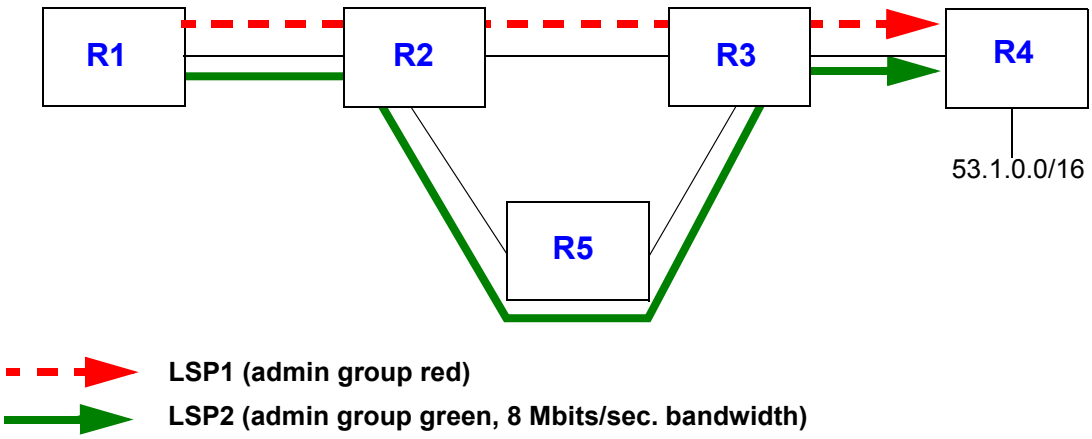

Figure 17-23 Traffic engineering with IS-IS

Note For simplicity, the configurations shown in this section are for *unidirectional* LSPs from R1 to R4. In most cases, you would also need to configure LSPs in the reverse direction, from R4 to R1.

The following is the configuration for R1:

```
! Create interfaces
interface create ip to-R2 address-netmask 153.1.1.13/16 port gi.2.1
interface add ip lo0 address-netmask 113.113.113.113/32

! Configure IS-IS
ip-router global set router-id 113.113.113.113
ip-router policy redistribute from-proto direct to-proto isis-level-1
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
```


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```
isis add interface lo0
isis add interface to-R2
isis set system-id 13.1313.1313.13
isis set interface to-R2 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis set level 1
isis set interface lo0 level 1
isis start

! Configure MPLS
mpls add interface to-R2
mpls set interface to-R2 admin-group red,green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls create label-switched-path LSP1 from 113.113.113.113 to 124.124.124.124
mpls create label-switched-path LSP2 from 113.113.113.113 to 124.124.124.124
mpls set label-switched-path LSP1 include red
mpls set label-switched-path LSP2 include green bps 8000000
mpls create policy to-53-net dst-ipaddr-mask 53.0.0/16 proto ip
mpls set label-switched-path LSP1 policy to-53-net
mpls start

! Enable and start RSVP
rsvp add interface to-R2
rsvp start
```

The following is the configuration for R2:

```
! Configure VLANs
smarttrunk create st.1 protocol no-protocol
smarttrunk add ports et.3.3 to st.1
smarttrunk add ports et.3.4 to st.1
vlan create to-R3 ip
vlan add ports st.1 to to-R3
vlan create to-R5 ip
vlan add ports et.3.5 to to-R5

! Create interfaces
interface create ip to-R1 address-netmask 153.1.1.12/16 port gi.6.1
interface create ip to-R3 address-netmask 192.1.1.12/24 vlan to-R3
interface create ip to-R5 address-netmask 186.1.1.12/8 vlan to-R5
interface add ip lo0 address-netmask 12.12.12.12/32

! Configure IS-IS
ip-router global set router-id 12.12.12.12
```


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```
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R3
isis add interface to-R5
isis add interface to-R1
isis set system-id 12.1212.1212.12
isis set level 1-and-2
isis set interface to-R3 level 1
isis set interface to-R1 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set interface to-R3 key-chain test1 authentication-method md5
isis set interface to-R5 level 1
isis set interface to-R5 key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis set interface to-R1 level 1
isis start

! Configure MPLS
mpls add interface all
mpls add interface lo0
mpls set interface to-R5 bandwidth 20000000
mpls set interface to-R3 admin-group red
mpls set interface to-R1 admin-group red,green
mpls set interface to-R5 admin-group green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for R3:

```
! Configure VLANs
smarttrunk create st.1 protocol no-protocol
smarttrunk add ports et.13.3 to st.1
smarttrunk add ports et.13.4 to st.1
vlan make trunk-port et.13.8
vlan create to-R2 ip
vlan add ports st.1 to to-R2
vlan create to-R5 ip
vlan add ports et.6.8 to to-R5
vlan create to-R4 ip id 22
vlan add ports et.13.8 to to-R4
```


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```
! Create interfaces
interface add ip lo0 address-netmask 15.15.15.15/32
interface create ip to-R2 address-netmask 192.1.1.15/24 vlan to-R2
interface create ip to-R5 address-netmask 187.1.1.15/16 vlan to-R5
interface create ip to-R4 address-netmask 185.1.1.15/16 vlan to-R4

! Configure IS-IS
ip-router global set router-id 15.15.15.15
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 id 255 type primary (key is encrypted)
isis add area 53.da05
isis add interface to-R5
isis add interface to-R4
isis add interface to-R2
isis add interface lo0
isis set system-id 15.1515.1515.15
isis set interface to-R4 level 1
isis set level 1-and-2
isis set interface to-R5 level 1
isis set interface to-R2 level 1
isis set area-key-chain test1 authentication-method md5
isis set interface to-R2 key-chain test1 authentication-method md5
isis set interface to-R4 key-chain test1 authentication-method md5
isis set interface to-R5 key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis set interface lo0 level 1
isis start

! Configure MPLS
mpls add interface all
mpls set interface to-R5 bandwidth 20000000
mpls set interface to-R5 admin-group green
mpls set interface to-R4 admin-group red,green
mpls set interface to-R2 admin-group red
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for R4:

```
! Configure VLANs
vlan create to-R3 ip id 22
vlan add ports et.16.23 to to-R3
```


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```
vlan create 53net ip
vlan add ports et.13.22 to 53net
vlan make trunk-port et.14.23

! Create interfaces
interface create ip to-R3 address-netmask 185.1.1.24/16 vlan to-R3
interface create ip to-R3 address-netmask 185.1.1.24/16 port et.16.23
interface create ip 53net address-netmask 53.1.1.22/16 vlan 53net

! Configure IS-IS
ip-router global set router-id 124.124.124.124
ip-router policy redistribute from-proto direct to-proto isis-level-1
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R3
isis set system-id 24.2424.2424.24
isis set level 1
isis set interface to-R3 level 1
isis set interface lo0 level 1
isis set interface to-R3 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis start

! Configure MPLS
mpls add interface to-R3
mpls set interface to-R3 admin-group red,green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Configure RSVP
rsvp add interface to-R3
rsvp start
```

The following is the configuration for R5:

```
! Configure VLANs
vlan create to-R2 ip
vlan add ports et.2.15 to to-R2
vlan create to-R3 ip
vlan add ports et.1.15 to to-R3
```


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```
! Create interfaces
interface create ip to-R2 address-netmask 186.1.1.26/8 vlan to-R2
interface create ip to-R3 address-netmask 187.1.1.26/16 vlan to-R3

! Configure IS-IS
ip-router global set router-id 126.126.126.126
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R2
isis add interface to-R3
isis set level 1
isis set system-id 26.2626.2626.26
isis set interface to-R2 level 1
isis set interface to-R3 level 1
isis set area-key-chain test1 authentication-method md5
isis set interface to-R2 key-chain test1 authentication-method md5
isis set interface to-R3 key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis start

! Configure MPLS
mpls add interface all
mpls set interface to-R2 admin-group green
mpls set interface to-R3 bandwidth 20000000
mpls set interface to-R2 bandwidth 20000000
mpls set interface to-R3 admin-group green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the **`mpls show label-switched-path LSP1 verbose`** command on R1 that shows the selected path for LSP1 in the **`cspf-path`** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group 'red' is applied on the routers.

```
R1# mpls show label-switched-paths LSP1 verbose

    Label-Switched-Path: "LSP1"
        to: 124.124.124.124             from: 113.113.113.113
        state: Up               lsp-id: 0xf
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <FROM_ADDR>
```


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```
        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 5000   retry-int: 3 sec.
            retry-count: 5000   next_retry_int: 0.000000 sec.
            bps: 0              preference: 7
            hop-limit: 255      opt-int: 600 sec.
            ott-index: 3        ref-count: 1
            mtu: 0
            cspf-path:  num-hops: 4
                153.1.1.13      - strict
                153.1.1.12      - strict
                192.1.1.15      - strict
                185.1.1.24      - strict
            include:            red
            record-route:
                153.1.1.12
                192.1.1.15
                185.1.1.24
```

The following is the **`mpls show label-switched-path LSP2 verbose`** command on R1 that shows the selected path for LSP2 in the **`cspf-path`** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group 'green' is applied on the routers. This LSP also has a bandwidth of 8 Mbps reserved on the path.

```
R1# mpls show label-switched-paths LSP2 verbose

    Label-Switched-Path: "LSP2"
        to: 124.124.124.124             from: 113.113.113.113
        state: Up               lsp-id: 0x12
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <FROM_ADDR BPS>

        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 5000   retry-int: 3 sec.
            retry-count: 5000   next_retry_int: 0.000000 sec.
            bps: 8000000        preference: 7
            hop-limit: 255      opt-int: 600 sec.
            ott-index: 6        ref-count: 1
            mtu: 0
            cspf-path:  num-hops: 5
                153.1.1.13      - strict
                153.1.1.12      - strict
                186.1.1.26      - strict
                187.1.1.15      - strict
```


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```
                185.1.1.24      - strict
            include:            green
            record-route:
                153.1.1.12
                186.1.1.26
                187.1.1.15
                185.1.1.24
```

The following command shows the IS-IS adjacencies on R1:

```
R1#  isis show adjacencies

Adjacencies

Interface   System         State  Level Hold(s) SNPA                   Priority
to-R2       R2             up     L1     9      802.2 0:0:0:a3:62:61    100
```

The following command shows the IS-IS traffic engineering database on R1:

```
R1# isis show ted
  TED database:
  NodeID:  R2(12.12.12.12)  Age: 1099 secs
  Protocol: IS-IS(1)
    To:  1212.1212.1212.0e, Local: 186.1.1.12
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
[0]             12 Mbps [1]             12 Mbps
[2]             12 Mbps [3]             12 Mbps
[4]             12 Mbps [5]             12 Mbps
[6]             12 Mbps [7]             12 Mbps

    To:  1212.1212.1212.0b, Local: 153.1.1.12
    Color:  0xe
    Static BW:              1 Gbps
    Reservable BW:              1 Gbps
    Available BW [priority]:
[0]              1 Gbps [1]              1 Gbps
[2]              1 Gbps [3]              1 Gbps
[4]              1 Gbps [5]              1 Gbps
[6]              1 Gbps [7]              1 Gbps

    To:  1212.1212.1212.0d, Local: 192.1.1.12
```


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```
    Color:  0x2
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]            100 Mbps [1]            100 Mbps
[2]            100 Mbps [3]            100 Mbps
[4]            100 Mbps [5]            100 Mbps
[6]            100 Mbps [7]            100 Mbps


  NodeID: 1212.1212.1212.0b00  Age: 1081 secs
  Protocol: IS-IS(1)
    To:  1313.1313.1313.00
    To:  1212.1212.1212.00

  NodeID: 1212.1212.1212.0d00  Age: 1076 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.00
    To:  1212.1212.1212.00

  NodeID: 1212.1212.1212.0e00  Age: 1076 secs
  Protocol: IS-IS(1)
    To:  2626.2626.2626.00
    To:  1212.1212.1212.00

  NodeID:  R1(113.113.113.113)  Age: 1092 secs
  Protocol: IS-IS(1)
    To:  0000.1717.1717.0a
    To:  1212.1212.1212.0b, Local: 153.1.1.13, Remote: 153.1.1.12
    Color:  0xa
    Static BW:              1 Gbps
    Reservable BW:              1 Gbps
    Available BW [priority]:
[0]            992 Mbps [1]            992 Mbps
[2]            992 Mbps [3]            992 Mbps
[4]            992 Mbps [5]            992 Mbps
[6]            992 Mbps [7]            992 Mbps


  NodeID:  R3(15.15.15.15)  Age: 1088 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.08, Local: 185.1.1.15
    Color:  0xa
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]             92 Mbps [1]             92 Mbps
[2]             92 Mbps [3]             92 Mbps
[4]             92 Mbps [5]             92 Mbps
[6]             92 Mbps [7]             92 Mbps
```


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```
    To:  1515.1515.1515.06, Local: 187.1.1.15
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
[0]             20 Mbps [1]             20 Mbps
[2]             20 Mbps [3]             20 Mbps
[4]             20 Mbps [5]             20 Mbps
[6]             20 Mbps [7]             20 Mbps

    To:  1212.1212.1212.0d, Local: 192.1.1.15, Remote: 192.1.1.12
    Color:  0x2
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]            100 Mbps [1]            100 Mbps
[2]            100 Mbps [3]            100 Mbps
[4]            100 Mbps [5]            100 Mbps
        [6]            100 Mbps [7]            100 Mbps


  NodeID: 1515.1515.1515.0600  Age: 1074 secs
  Protocol: IS-IS(1)
    To:  2626.2626.2626.00
    To:  1515.1515.1515.00

  NodeID: 1515.1515.1515.0800  Age: 1070 secs
  Protocol: IS-IS(1)
    To:  2424.2424.2424.00
    To:  1515.1515.1515.00

  NodeID:  R4(124.124.124.124)  Age: 1065 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.08, Local: 185.1.1.24, Remote: 185.1.1.15
    Color:  0xa
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
        [0]            100 Mbps [1]            100 Mbps
        [2]            100 Mbps [3]            100 Mbps
        [4]            100 Mbps [5]            100 Mbps
        [6]            100 Mbps [7]            100 Mbps

  NodeID:  R5(126.126.126.126)  Age: 1093 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.06, Local: 187.1.1.26, Remote: 187.1.1.15
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
```


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```
    Available BW [priority]:
        [0]             12 Mbps [1]             12 Mbps
        [2]             12 Mbps [3]             12 Mbps
        [4]             12 Mbps [5]             12 Mbps
        [6]             12 Mbps [7]             12 Mbps

    To:  1212.1212.1212.0e, Local: 186.1.1.26, Remote: 186.1.1.12
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
        [0]             20 Mbps [1]             20 Mbps
        [2]             20 Mbps [3]             20 Mbps
        [4]             20 Mbps [5]             20 Mbps
        [6]             20 Mbps [7]             20 Mbps
```

17.7.3 IGP Shortcuts

Link-state IGPs, such as IS-IS and OSPF, use shortest path calculations to produce destination-first hop entries in the routing table. With normal hop-by-hop routing, the first hop is a *physical* interface on the router. A *logical* interface, which represents an explicit path LSP, can also be installed in the routing table to be used by the IGP as the first hop to a specified destination. Thus, the LSP is used as a "shortcut" to a specific destination in the network.

Using IGP shortcuts provides the following benefits:

- control of traffic to destinations that do not support MPLS LSPs
- allows LSPs to be deployed on a regional basis

IGP shortcuts can be enabled on a per-router basis (it is disabled by default). When IGP shortcuts are enabled, each router maintains a list of IGP shortcuts that originate at the local router and the ID of the router at the opposite end of the shortcut. Traffic to nodes that are at the tail end of a shortcut and to nodes that are downstream from the end of a shortcut will flow over the shortcut.

To enable IGP shortcuts on RS routers that use OSPF as the IGP:

```
ip-router global set install-lsp-routes on
ospf set igp-shortcuts on
```

To enable IGP shortcuts on RS routers that use IS-IS as the IGP:

```
ip-router global set install-lsp-routes on
isis set igp-shortcuts enable
```


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IS-IS IGP Shortcuts Example

Refer to the example routing network shown in Figure 17-23. On R1, packets for the destination 53.1.0.0/16 (on R4) use the gateway IP address 153.1.1.12 as the immediate next-hop. In the routing table display on R1 shown below, the entry for destination 53.1.0.0/16 is shown in **bold**:

```
R1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.61.0.0/16         directly connected   -         en0
12.12.12.12          153.1.1.12           ISIS_L1   to-R2
15.15.15.15          153.1.1.12           ISIS_L1   to-R2
26.26.26.26          153.1.1.12           ISIS_L1   to-R2
27.0.0.0/8           153.1.1.12           ISIS_L1   to-R2
53.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
55.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
92.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
95.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
96.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
97.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
101.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
102.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
103.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
104.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
113.113.113.113      113.113.113.113      -         lo0
124.124.124.124      Unnumbered           -         LSP1
126.126.126.126      153.1.1.12           ISIS_L1   to-R2
127.0.0.1            127.0.0.1            -         lo0
134.141.0.0/16       10.61.1.1            Static    en0
153.1.0.0/16         directly connected   -         to-R2
185.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
186.0.0.0/8          153.1.1.12           ISIS_L1   to-R2
187.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
192.1.1.0/24         153.1.1.12           ISIS_L1   to-R2
195.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
```

To enable IGP shortcuts on the router R1, enter the following command:

```
R1(config)# ip-router global set install-lsp-routes on
R1(config)# isis set igp-shortcuts enable
```


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Now, the routing table on R1 includes the constrained path LSPs configured in *"Constrained Path Selection Configuration Example for IS-IS Traffic Engineering"*. Packets to the destination 53.1.0.0/16, as well as other destinations, can be forwarded using the LSPs LSP1 or LSP2, as shown in the routing table display below:

```
R1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.61.0.0/16         directly connected   -         en0
12.12.12.12          153.1.1.12           ISIS_L1   to-R2
15.15.15.15          153.1.1.12           ISIS_L1   to-R2
27.0.0.0/8           Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
                     Unnumbered           ISIS_L1   LSP2
53.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
55.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
78.1.0.0/16          directly connected   -         78net
92.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
95.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
96.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
97.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
101.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
102.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
103.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
104.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
113.113.113.113      113.113.113.113      -         lo0
124.124.124.124      Unnumbered           -         LSP1
126.126.126.126      153.1.1.12           ISIS_L1   to-R2
127.0.0.1            127.0.0.1            -         lo0
134.141.0.0/16       10.61.1.1            Static    en0
142.1.1.0/24         directly connected   -         142net
143.1.0.0/16         directly connected   -         143net
153.1.0.0/16         directly connected   -         to-R2
185.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
186.0.0.0/8          153.1.1.12           ISIS_L1   to-R2
187.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
192.1.1.0/24         153.1.1.12           ISIS_L1   to-R2
195.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
```


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Advertising IGP Shortcuts

IGP shortcuts need to be advertised so that other routers in the autonomous system can calculate paths that use the LSP. You advertise these shortcuts with the **isis add label-switched-path** command for IS-IS networks and with the **ospf add label-switched-path** command for OSPF networks.

Note Each LSP is advertised as a unidirectional, point-to-point link. OSPF and IS-IS both verify that there is a bidirectional connection between nodes before using an advertised link. Therefore, you need to configure two LSPs, one in each direction, for paths between two LSRs that will be advertised in IS-IS or OSPF autonomous systems.

The LSP is advertised as a unidirectional, point-to-point link. The advertisement contains:

- the source address of the LSP (usually the address of the local router)
- the destination address of the LSP (usually the address of the egress router)
- a metric value

The metric value is an optional parameter configured for the LSP with the **mpls create|set label-switched-path** command. If no metric value is configured for the LSP with the **isis**, **ospf**, or **mpls** commands, then a metric value of 1 is used.

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18 ROUTING POLICY CONFIGURATION

The RS family of routers supports extremely flexible routing policies. The RS allows the network administrator to control import and export of routing information based on criteria including:

- Individual protocol
- Source and destination autonomous system
- Source and destination interface
- Previous hop router
- Autonomous system path
- Tag associated with routes
- Specific destination address

The network administrator can specify a preference level for each combination of routing information being imported by using a flexible masking capability.

The RS also provides the ability to create advanced and simple routing policies. Simple routing policies provide a quick route redistribution between various routing protocols (RIP, OSPF, IS-IS and BGP). Advanced routing policies provide more control over route redistribution.

18.1 PREFERENCE

Preference is the value the RS routing process uses to order preference of routes from one protocol or peer over another. Preference can be set using several different configuration commands. Preference can be set based on one network interface over another, from one protocol over another, or from one remote gateway over another. Preference may not be used to control the selection of routes within an Interior Gateway Protocol (IGP). This is accomplished automatically by the protocol based on metric.

Preference may be used to select routes from the same Exterior Gateway Protocol (EGP) learned from different peers or autonomous systems. Each route has only one preference value associated with it, even though the preference can be set at many places using configuration commands. The last or most specific preference value set for a route is the value used. A preference value is an arbitrarily assigned value used to determine the order of routes to the same destination in a single routing database. The active route is chosen by the lowest preference value.

A default preference is assigned to each source from which the RS routing process receives routes. Preference values range from 0 to 255 with the lowest number indicating the most preferred route.

The following table summarizes the default preference values for routes learned in various ways. The table lists the CLI commands that set preference, and shows the types of routes to which each CLI command applies. A default preference for each type of route is listed, and the table notes preference precedence between protocols. The narrower the scope of the statement, the higher precedence its preference value is given, but the smaller the set of routes it affects.

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Table 18-1 Default preference values

Preference	Defined by CLI Command	Default
Direct connected networks	**ip-router global set interface**	0
OSPF routes	**ospf**	10
Static routes from config	**ip add route**	60
RIP routes	**rip set preference**	100
Point-to-point interface		110
Routes to interfaces that are down	**ip-router global set interface down-preference**	120
Aggregate/generate routes	**aggr-gen**	130
OSPF AS external routes	**ospf set ase-defaults preference**	150
BGP routes	**bgp set preference**	170
IS-IS routes	**isis set preference**	

18.1.1 Import Policies

Import policies control the importation of routes from routing protocols and their installation in the routing databases (Routing Information Base and Forwarding Information Base). Import Policies determine which routes received from other systems are used by the RS routing process. Every import policy can have up to two components:

- Import-Source
- Route-Filter

Import-Source

This component specifies the source of the imported routes. It can also specify the preference to be associated with the routes imported from this source.

The routes to be imported can be identified by their associated attributes:

- Type of the source protocol (RIP, OSPF, BGP).
- Source interface or gateway from which the route was received.
- Source autonomous system from which the route was learned.
- AS path associated with a route. Besides autonomous system, BGP also supports importation of routes using AS path regular expressions and AS path options.
- If multiple communities are specified using the optional-attributes-list, only updates carrying all of the specified communities will be matched. If the specified optional-attributes-list has the value **none** for the **well-known-community** option, then only updates lacking the community attribute will be matched.

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In some cases, a combination of the associated attributes can be specified to identify the routes to be imported.

Note It is quite possible for several BGP import policies to match a given update. If more than one policy matches, the first matching policy will be used. All later matching policies will be ignored. For this reason, it is generally desirable to order import policies from most to least specific. An import policy with an optional-attributes-list will match any update with any (or no) communities.

The importation of RIP routes may be controlled by source interface and source gateway. RIP does not support the use of preference to choose between RIP routes. That is left to the protocol metrics.

Due to the nature of OSPF, only the importation of ASE routes may be controlled. OSPF intra-and inter-area routes are always imported into the routing table with a preference of 10. If a tag is specified with the import policy, routes with the specified tag will only be imported. It is only possible to restrict the importation of OSPF ASE routes when functioning as an AS border router.

Like the other interior protocols, preference cannot be used to choose between OSPF ASE routes. That is done by the OSPF costs.

Route-Filter

This component specifies the individual routes which are to be imported or restricted. The preference to be associated with these routes can also be explicitly specified using this component.

The preference associated with the imported routes are inherited unless explicitly specified. If there is no preference specified with a route-filter, then the preference is inherited from the one specified with the import-source.

Every protocol (RIP, OSPF, and BGP) has a configurable parameter that specifies the default-preference associated with routes imported to that protocol. If a preference is not explicitly specified with the route-filter, as well as the import-source, then it is inherited from the default-preference associated with the protocol for which the routes are being imported.

18.1.2 Export Policies

Export policies control the redistribution of routes to other systems. They determine which routes are advertised by the Unicast Routing Process to other systems. Every export policy can have up to three components:

- Export-Destination
- Export-Source
- Route-Filter

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Export-Destination

This component specifies the destination where the routes are to be exported. It also specifies the attributes associated with the exported routes. The interface, gateway, or the autonomous system to which the routes are to be redistributed are a few examples of export-destinations. The metric, type, tag, and AS-Path are a few examples of attributes associated with the exported routes.

Export-Source

This component specifies the source of the exported routes. It can also specify the metric to be associated with the routes exported from this source.

The routes to be exported can be identified by their associated attributes:

- Their protocol type (RIP, OSPF, BGP, Static, Direct, Aggregate, IS-IS).
- Interface or the gateway from which the route was received.
- Autonomous system from which the route was learned.
- AS path associated with a route. When BGP is configured, all routes are assigned an AS path when they are added to the routing table. For interior routes, this AS path specifies IGP as the origin and no ASs in the AS path (the current AS is added when the route is exported). For BGP routes, the AS path is stored as learned from BGP.
- Tag associated with a route. Both OSPF and RIP version 2 currently support tags. All other protocols have a tag of zero.

In some cases, a combination of the associated attributes can be specified to identify the routes to be exported.

Route-Filter

This component specifies the individual routes which are to exported or restricted. The metric to be associated with these routes can also be explicitly specified using this component.

The metric associated with the exported routes are inherited unless explicitly specified. If there is no metric specified with a route-filter, then the metric is inherited from the one specified with the export-source.

If a metric was not explicitly specified with both the route-filter and the export-source, then it is inherited from the one specified with the export-destination.

Every protocol (RIP, OSPF, BGP, and IS-IS) has a configurable parameter that specifies the default-metric associated with routes exported to that protocol. If a metric is not explicitly specified with the route-filter, export-source as well as export-destination, then it is inherited from the default-metric associated with the protocol to which the routes are being exported.

18.1.3 Specifying a Route Filter

Routes are filtered by specifying a route-filter that will match a certain set of routes by destination, or by destination and mask. Among other places, route filters are used with martians and in import and export policies.

The action taken when no match is found is dependent on the context. For instance, a route that does match any of the route-filters associated with the specified import or export policies is rejected.

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A route will match the most specific filter that applies. Specifying more than one filter with the same destination, mask, and modifiers generates an error.

There are three possible formats for a route filter. Not all of these formats are available in all places. In most cases, it is possible to associate additional options with a filter. For example, while creating a martian, it is possible to specify the **`allow`** option, while creating an import policy, one can specify a **`preference`**, and while creating an export policy one can specify a **`metric`**.

The three forms of a route-filter are:

Network	[exact | refines | between number,number]
Network/mask	[exact | refines | between number,number]
Network/masklen	[exact | refines | between number,number]

Matching usually requires both an address and a mask, although the mask is implied in the shorthand forms listed below. These three forms vary in how the mask is specified. In the first form, the mask is implied to be the natural mask of the network. In the second, the mask is explicitly specified. In the third, the mask is specified by the number of contiguous one bits.

If no optional parameters (exact, refines, or between) are specified, any destination that falls in the range given by the network and mask is matched, so the mask of the destination is ignored. If a natural network is specified, the network, any subnets, and any hosts will be matched. Three optional parameters that cause the mask of the destination to also be considered are:

Exact	Specifies that the mask of the destination must match the supplied mask exactly. This is used to match a network, but no subnets or hosts of that network.
Refines	Specifies that the mask of the destination must be more specified (i.e., longer) than the filter mask. This is used to match subnets and/or hosts of a network, but not the network.
Between number, number	Specifies that the mask of the destination must be as or more specific (i.e., as long as or longer) than the lower limit (the first number parameter) and no more specific (i.e., as long as or shorter) than the upper limit (the second number). Note that exact and refines are both special cases of between.

18.1.4 Aggregates and Generates

Route aggregation is a method of generating a more general route, given the presence of a specific route. It is used, for example, at an autonomous system border to generate a route to a network to be advertised via BGP given the presence of one or more subnets of that network learned via OSPF. The routing process does not perform any aggregation unless explicitly requested.

Route aggregation is also used by regional and national networks to reduce the amount of routing information passed around. With careful allocation of network addresses to clients, regional networks can just announce one route to regional networks instead of hundreds.

Aggregate routes are not actually used for packet forwarding by the originator of the aggregate route, but only by the receiver (if it wishes). Instead of requiring a route-peer to know about individual subnets which would increase the size of its routing table, the peer is only informed about an aggregate-route which contains all the subnets.

Like export policies, aggregate-routes can have up to three components:

- Aggregate-Destination
- Aggregate-Source

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- Route-Filter

Aggregate-Destination

This component specifies the aggregate/summarized route. It also specifies the attributes associated with the aggregate route. The preference to be associated with an aggregate route can be specified using this component.

Aggregate-Source

This component specifies the source of the routes contributing to an aggregate/summarized route. It can also specify the preference to be associated with the contributing routes from this source. This preference can be overridden by explicitly specifying a preference with the route-filter.

The routes contributing to an aggregate can be identified by their associated attributes:

- Protocol type (RIP, OSPF, BGP, Static, Direct, Aggregate, IS-IS).
- Autonomous system from which the route was learned.
- AS path associated with a route. When BGP is configured, all routes are assigned an AS path when they are added to the routing table. For interior routes, this AS path specifies IGP as the origin and no ASs in the AS path (the current AS is added when the route is exported). For BGP routes, the AS path is stored as learned from BGP.
- Tag associated with a route. Both OSPF and RIP version 2 currently support tags. All other protocols have a tag of zero.

In some cases, a combination of the associated attributes can be specified to identify the routes contributing to an aggregate.

Route-Filter

This component specifies the individual routes that are to be aggregated or summarized. The preference to be associated with these routes can also be explicitly specified using this component.

The contributing routes are ordered according to the aggregation preference that applies to them. If there is more than one contributing route with the same aggregating preference, the route's own preferences are used to order the routes. The preference of the aggregate route will be that of contributing route with the lowest aggregate preference.

A route may only contribute to an aggregate route that is more general than itself; it must match the aggregate under its mask. Any given route may only contribute to one aggregate route, which will be the most specific configured, but an aggregate route may contribute to a more general aggregate.

An aggregate-route only comes into existence if at least one of its contributing routes is active.

18.1.5 Authentication

Authentication guarantees that routing information is only imported from trusted routers. Many protocols like RIP V2 and OSPF provide mechanisms for authenticating protocol exchanges. A variety of authentication schemes can be used. Authentication has two components – an Authentication Method and an Authentication Key. Many protocols allow different authentication methods and keys to be used in different parts of the network.

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Authentication Methods

There are two main authentication methods:

Simple Password In this method, an authentication key of up to 8 characters is included in the packet. If this does not match what is expected, the packet is discarded. This method provides little security, as it is possible to learn the authentication key by watching the protocol packets.

MD5 This method uses the MD5 algorithm to create a crypto-checksum of the protocol packet and an authentication key of up to 16 characters. The transmitted packet does not contain the authentication key itself; instead, it contains a crypto-checksum, called the digest. The receiving router performs a calculation using the correct authentication key and discard the packet if the digest does not match. In addition, a sequence number is maintained to prevent the replay of older packets. This method provides a much stronger assurance that routing data originated from a router with a valid authentication key.

Many protocols allow the specification of two authentication keys per interface. Packets are always sent using the primary keys, but received packets are checked with both the primary and secondary keys before being discarded.

Authentication Keys and Key Management

An authentication key permits the generation and verification of the authentication field in protocol packets. In many situations, the same primary and secondary keys are used on several interfaces of a router. To make key management easier, the concept of a *key-chain* was introduced. Each key-chain has an identifier and can contain up to two keys. One key is the primary key and other is the secondary key. Outgoing packets use the primary authentication key, but incoming packets may match either the primary or secondary authentication key. In Configure mode, instead of specifying the key for each interface (which can be up to 16 characters long), you can specify a key-chain identifier.

The RS supports MD5 specification of OSPF RFC 2178 which uses the MD5 algorithm and an authentication key of up to 16 characters. Thus there are now three authentication schemes available per interface: none, simple and RFC 2178 OSPF MD5 authentication. It is possible to configure different authentication schemes on different interfaces.

RFC 2178 allows multiple MD5 keys per interface. Each key has two times associated with the key:

- A time period that the key will be generated
- A time period that the key will be accepted

The RS only allows one MD5 key per interface. Also, there are no options provided to specify the time period during which the key would be generated and accepted; the specified MD5 key is always generated and accepted. Both these limitations would be removed in a future release.

18.2 CONFIGURING SIMPLE ROUTING POLICIES

Simple routing policies provide an efficient way for routing information to be exchanged between routing protocols. The **`redistribute`** command can be used to redistribute routes from one routing domain into another routing domain. Redistribution of routes between routing domains is based on route policies. A route policy is a set of conditions based on which routes are redistributed. While the **`redistribute`** command may fulfill the export policy requirement for most users, complex export policies may require the use of the commands listed under Export Policies.

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The general syntax of the redistribute command is as follows:

ip-router policy redistribute from-proto <*protocol*> **to-proto** <*protocol*> [**network** <*ipAddr-mask*> [**exact|refines|between** <*low-high*>]] [**metric** <*number*>|**restrict**] [**source-as** <*number*>] [**target-as** <*number*>]

The **from-proto** parameter specifies the protocol of the source routes. The values for the from-proto parameter can be **rip**, **ospf**, **bgp**, **direct**, **static**, **aggregate, isis-level-1, isis-level-2** and **ospf-ase**. The **to-proto** parameter specifies the destination protocol where the routes are to be exported. The values for the **to-proto** parameter can be **rip**, **ospf, ospf-nssa, isis-level-1, isis-level-2,** and **bgp**. The network parameter provides a means to define a filter for the routes to be distributed. The network parameter defines a filter that is made up of an IP address and a mask. Routes that match the filter are considered as eligible for redistribution.

Every protocol (RIP, OSPF, IS-IS and BGP) has a configurable parameter that specifies the default-metric associated with routes exported to that protocol. If a metric is not explicitly specified with the redistribute command, then it is inherited from the default-metric associated with the protocol to which the routes are being exported.

18.2.1 Redistributing Static Routes

Static routes may be redistributed to another routing protocol such as RIP or OSPF by the following command. The **network** parameter specifies the set of static routes that will be redistributed by this command. If all static routes are to be redistributed set the **network** parameter to **all**. Note that the **network** parameter is a filter that is used to specify routes that are to be redistributed.

To redistribute static routes, enter one of the following commands in Configure mode:

To redistribute static routes into RIP.	**ip-router policy redistribute from-proto static to-proto rip network all**
To redistribute static routes into OSPF.	**ip-router policy redistribute from-proto static to-proto ospf network all**

18.2.2 Redistributing Directly Attached Networks

Routes to directly attached networks are redistributed to another routing protocol such as RIP or OSPF by the following command. The **network** parameter specifies a set of routes that will be redistributed by this command. If all direct routes are to be redistributed set the **network** parameter to **all**. Note that the **network** parameter is a filter that is used to specify routes that are to be redistributed.

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To redistribute direct routes, enter one of the following commands in Configure mode:

To redistribute direct routes into RIP.	**ip-router policy redistribute from-proto direct to-proto rip network all**
To redistribute direct routes into OSPF.	**ip-router policy redistribute from-proto direct to-proto ospf network all**

18.2.3 Redistributing RIP into RIP

The RS routing process requires RIP redistribution into RIP if a protocol is redistributed into RIP.

To redistribute RIP into RIP, enter the following command in Configure mode:

To redistribute RIP into RIP.	**ip-router policy redistribute from-proto rip to-proto rip**

18.2.4 Redistributing RIP into OSPF

RIP routes may be redistributed to OSPF.

To redistribute RIP into OSPF, enter the following command in Configure mode:

To redistribute RIP into OSPF.	**ip-router policy redistribute from-proto rip to-proto ospf**

18.2.5 Redistributing OSPF to RIP

For the purposes of route redistribution and import-export policies, OSPF intra- and inter-area routes are referred to as **ospf** routes, and external routes redistributed into OSPF are referred to as **ospf-ase** routes. Examples of **ospf-ase** routes include **static** routes, **rip** routes, **direct** routes, **bgp** routes, or **aggregate** routes, which are redistributed into an OSPF domain.

OSPF routes may be redistributed into RIP. To redistribute OSPF into RIP, enter the following command in Configure mode:

To redistribute ospf-ase routes into RIP.	**ip-router policy redistribute from-proto ospf-ase to-proto rip**
To redistribute ospf routes into RIP.	**ip-router policy redistribute from-proto ospf to-proto rip**

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18.2.6 Redistributing Aggregate Routes

The **aggregate** parameter causes an aggregate route with the specified IP address and subnet mask to be redistributed.

Note The aggregate route must first be created using the **aggr-gen** command**.** This command creates a specified aggregate route for routes that match the aggregate.

To redistribute aggregate routes, enter one of the following commands in Configure mode:

To redistribute aggregate routes into RIP.	**ip-router policy redistribute from-proto aggregate to-proto rip**
To redistribute aggregate routes into OSPF.	**ip-router policy redistribute from-proto aggregate to-proto ospf**

18.2.7 Simple Route Redistribution Example: Redistribution into RIP

For all examples given in this section, refer to the configurations shown in Figure 18-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its RIP configuration

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
 interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure a default route through 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route default gateway 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure static routes to the 135.3.0.0 subnets reachable through
! R3.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 135.3.1.0/24 gateway 130.1.1.3
 ip add route 135.3.2.0/24 gateway 130.1.1.3
 ip add route 135.3.3.0/24 gateway 130.1.1.3
```


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```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.190.1.2
 ip add route 160.1.5.0/24 gateway 120.190.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip start
 rip set default-metric 2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Interface Configuration. Create a RIP interfaces, and set
 ! their type to (version II, multicast).
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip add interface to-r41
 rip add interface to-r42
 rip add interface to-r6
 rip set interface to-r41 version 2 type multicast
 rip set interface to-r42 version 2 type multicast
 rip set interface to-r6  version 2 type multicast
```

Exporting a Given Static Route to All RIP Interfaces

Router R1 has several static routes of which one is the default route. We would export this default route over all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network default
```

Exporting All Static Routes to All RIP Interfaces

Router R1 has several static routes. We would export these routes over all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network all
```

Exporting All Static Routes Except the Default Route to All RIP Interfaces

Router R1 has several static routes. We would export all these routes except the default route to all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network all
ip-router policy redistribute from-proto static to-proto rip network default restrict
```


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18.2.8 Simple Route Redistribution Example: Redistribution into OSPF

For all examples given in this section, refer to the configurations shown in Figure 18-2.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
  interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
   interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
   interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
   interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
   interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ip add route 202.1.0.0/16 gateway 120.1.1.2
   ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ospf start
   ospf create area 140.1.0.0
   ospf create area backbone
   ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ospf add interface 140.1.1.1 to-area 140.1.0.0
   ospf add interface 140.1.2.1 to-area 140.1.0.0
   ospf add interface 140.1.3.1 to-area 140.1.0.0
   ospf add interface 130.1.1.1 to-area backbone
```

Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We would like to export all these static routes and direct-routes (routes to connected networks) into OSPF.

```
ip-router policy redistribute from-proto static to-proto ospf
ip-router policy redistribute from-proto direct to-proto ospf
```


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Note The network parameter specifying the network-filter is optional. The default value for this parameter is **all**, indicating all networks. Since in the above example, we would like to export all static and direct routes into OSPF, we have not specified this parameter.

Exporting All RIP, Interface & Static Routes to OSPF

Note Also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 18-2, suppose we decide to run RIP Version 2 on network 120.190.0.0/16, connecting routers R1 and R2.

Router R1 would like to export all RIP, interface, and static routes to OSPF.

```
ip-router policy redistribute from-proto rip to-proto ospf
ip-router policy redistribute from-proto direct to-proto ospf
ip-router policy redistribute from-proto static to-proto ospf
```

Router R1 would also like to export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

```
ip-router policy redistribute from-proto direct to-proto rip
ip-router policy redistribute from-proto static to-proto rip
ip-router policy redistribute from-proto rip to-proto rip
ip-router policy redistribute from-proto ospf to-proto rip
ip-router policy redistribute from-proto ospf-ase to-proto rip
```

18.3 CONFIGURING ADVANCED ROUTING POLICIES

Advanced Routing Policies are used for creating complex import/export policies that cannot be done using the redistribute command. Advanced export policies provide granular control over the targets where the routes are exported, the source of the exported routes, and the individual routes which are exported. It provides the capability to send different routes to the various route-peers. They can be used to provide the same route with different attributes to the various route-peers.

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Import policies control the importation of routes from routing protocols and their installation in the routing database (Routing Information Base and Forwarding Information Base). Import policies determine which routes received from other systems are used by the RS routing process. Using import policies, it is possible to ignore route updates from an unreliable peer and give better preference to routes learned from a trusted peer.

18.3.1 Export Policies

Advanced export policies can be constructed from one or more of the following building blocks:

- Export Destinations - This component specifies the destination where the routes are to be exported. It also specifies the attributes associated with the exported routes. The interface, gateway or the autonomous system to which the routes are to be redistributed are a few examples of export-destinations. The metric, type, tag, and AS-Path are a few examples of attributes associated with the exported routes.
- Export Sources - This component specifies the source of the exported routes. It can also specify the metric to be associated with the routes exported from this source. The routes to be exported can be identified by their associated attributes, such as protocol type, interface or the gateway from which the route was received, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be distributed. Routes that match a filter are considered as eligible for redistribution. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for redistribution. The identifier associated with a route-filter is used in the **ip-router policy export** command.
  - Specifying the networks as needed in the **ip-router policy export** command.

  If you want to create a complex route-filter, and you intend to use that route-filter in several export policies, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

After you create one or more building blocks, they are tied together by the **iprouter policy export** command.

To create route export policies, enter the following command in Configure mode:

Create an export policy.	**ip-router policy export destination** <*exp-dest-id*> **[source** <*exp-src-id*> **[filter** <*filter-id*>**|[network** <*ipAddr-mask*> **[exact|refines|between** <*low-high*>**] [metric** <*number*>**|restrict]]]]**

<*exp-dest-id*> The identifier of the export-destination which determines where the routes are to be exported. If no routes to a particular destination are to be exported, then no additional parameters are required.

<*exp-src-id*> If specified, is the identifier of the export-source which determines the source of the exported routes. If a export-policy for a given export-destination has more than one export-source, then the **ip-router policy export destination** <*exp-dest-id*> command should be repeated for each <*exp-src-id*>.

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<*filter-id*> If specified, is the identifier of the route-filter associated with this export-policy. If there is more than one route-filter for any export-destination and export-source combination, then the **ip-router policy export destination** <*exp-dest-id*> **source** <*exp-src-id*> command should be repeated for each <*filter-id*>.

18.3.2 Creating an Export Destination

To create an export destination, enter one the following commands in Configure mode:

Create a RIP export destination.	**ip-router policy create rip-export-destination** <*name*>
Create an OSPF export destination.	**ip-router policy create ospf-export-destination** <*name*>
Create an IS-IS export destination.	**ip-router policy create isis-export-destination** <*name*>

18.3.3 Creating an Export Source

To create an export source, enter one of the following commands in Configure mode:

Create a RIP export source.	**ip-router policy create rip-export-source** <*name*>
Create an OSPF export source.	**ip-router policy create ospf-export-source** <*name*>
Create an IS-IS export source.	**ip-router policy create isis-export-source** <*name*>

18.3.4 Import Policies

Import policies can be constructed from one or more of the following building blocks:

- Import-source - This component specifies the source of the imported routes. It can also specify the preference to be associated with the routes imported from this source. The routes to be imported can be identified by their associated attributes, including source protocol, source interface, or gateway from which the route was received, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be imported. Routes that match a filter are considered as eligible for importation. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for importation. The identifier associated with a route-filter is used in the **ip-router policy import** command.
  - Specifying the networks as needed in the **ip-router policy import** command.

  If you want to create a complex route-filter, and you intend to use that route-filter in several import policies, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

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After you create one or more building blocks, they are tied together by the **ip-router policy import** command.

To create route import policies, enter the following command in Configure mode:

Create an import policy.	**ip-router policy import source** <*imp-src-id*> **[filter** <*filter-id*>**|[network** <*ipAddr-mask*> **[exact|refines|between** <*low-high*>**] [preference** <*number*>**|restrict]]]**

<*imp-src-id*> The identifier of the import-source that determines the source of the imported routes. If no routes from a particular source are to be imported, then no additional parameters are required.

<*filter-id*> If specified, is the identifier of the route-filter associated with this import-policy. If there is more than one route-filter for any import-source, then the **ip-router policy import source** <*imp-src-id*> command should be repeated for each <*filter-id*>.

18.3.5 Creating an Import Source

Import sources specify the routing protocol from which the routes are imported. The source may be RIP or OSPF.

To create an import source, enter one of the following commands in Configure mode:

Create a RIP import destination.	**ip-router policy create rip-import-source** <*name*>
Create an OSPF import destination.	**ip-router policy create ospf-import-source** <*name*>

18.3.6 Creating a Route Filter

Route policies are defined by specifying a set of filters that will match a certain route by destination or by destination and mask.

To create route filters, enter the following command in Configure mode:

Create a route filter.	**ip-router policy create filter** <*name-id*> **network** <*IP-address/mask*>

18.3.7 Creating an Aggregate Route

Route aggregation is a method of generating a more general route, given the presence of a specific route. The routing process does not perform any aggregation unless explicitly requested. Aggregate-routes can be constructed from one or more of the following building blocks:

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- Aggregate-Destination - This component specifies the aggregate/summarized route. It also specifies the attributes associated with the aggregate route. The preference to be associated with an aggregate route can be specified using this component.
- Aggregate-Source - This component specifies the source of the routes contributing to an aggregate/summarized route. It can also specify the preference to be associated with the contributing routes from this source. The routes contributing to an aggregate can be identified by their associated attributes, including protocol type, tag associated with a route, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be aggregated or summarized. Routes that match a filter are considered as eligible for aggregation. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for aggregation. The identifier associated with a route-filter is used in the **ip-router policy aggr-gen** command.
  - Specifying the networks as needed in the **ip-router policy aggr-gen** command.
- If you want to create a complex route-filter, and you intend to use that route-filter in several aggregates, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

After you create one or more building blocks, they are tied together by the **ip-router policy aggr-gen** command.

To create aggregates, enter the following command in Configure mode:

Create an aggregate route.	**ip-router policy aggr-gen destination** <*aggr-dest-id*> [source <*aggr-src-id*> **[filter** <*filter-id*>**|[network** <*ipAddr-mask*> **[exact|refines|between** <*low-high*>**]** **[preference** <*number*>**|restrict]]]]**

<*aggr-dest-id*> The identifier of the aggregate-destination that specifies the aggregate/summarized route.

<*aggr-src-id*> The identifier of the aggregate-source that contributes to an aggregate route. If an aggregate has more than one aggregate-source, then the **ip-router policy aggr-gen destination** <*aggr-dest-id*> command should be repeated for each <*aggr-src-id*>.

<*filter-id*> The identifier of the route-filter associated with this aggregate. If there is more than one route-filter for any aggregate-destination and aggregate-source combination, then the **ip-router policy aggr-gen destination** <*aggr-dest-id*> **source** <*aggr-src-id*> command should be repeated for each <*filter-id*>.

18.3.8 Creating an Aggregate Destination

To create an aggregate destination, enter the following command in Configure mode:

Create an aggregate destination.	**ip-router policy create aggr-gen-dest** <*name*> **network** <*ipAddr-mask*>

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18.3.9 Creating an Aggregate Source

To create an aggregate source, enter the following command in Configure mode:

Create an aggregate source.	**ip-router policy create aggr-gen-source** <*name*> **protocol** <*protocol-name*>

18.3.10 Import Policies Example: Importing from RIP

The importation of RIP routes may be controlled by any of protocol, source interface, or source gateway. If more than one is specified, they are processed from most general (protocol) to most specific (gateway).

RIP does not support the use of preference to choose between routes of the same protocol. That is left to the protocol metrics.

For all examples in this section, refer to the configuration shown in Figure 18-1.

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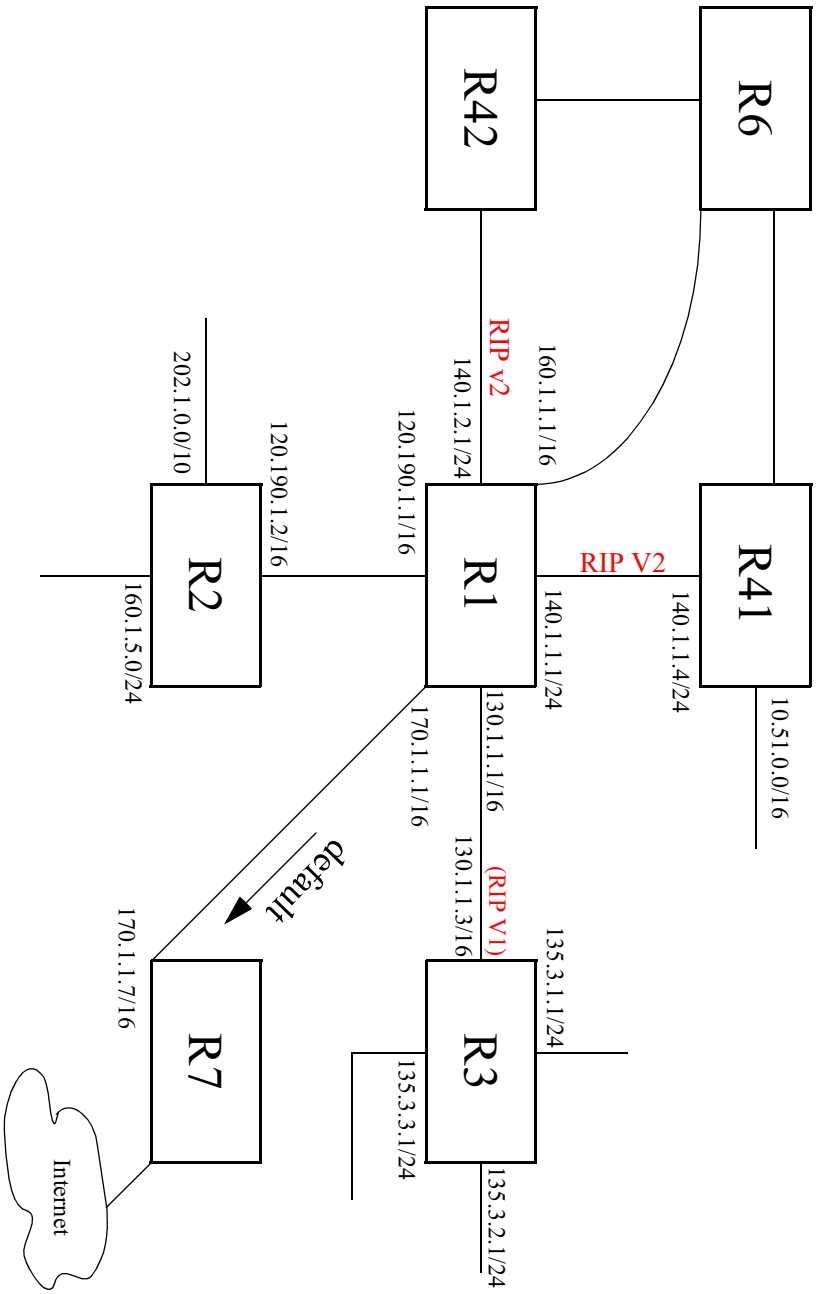

Figure 18-1 Exporting to RIP

The configuration commands shown below for router R1:

- Determine the IP address for each interface.
- Specify the static routes configured on the router.
- Determine its RIP configuration.

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```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure a default route through 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route default gateway 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the 135.3.0.0 subnets reachable through
! R3.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route 135.3.1.0/24 gateway 130.1.1.3
ip add route 135.3.2.0/24 gateway 130.1.1.3
ip add route 135.3.3.0/24 gateway 130.1.1.3
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route 202.1.0.0/16 gateway 120.190.1.2
ip add route 160.1.5.0/24 gateway 120.190.1.2
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! RIP Box Level Configuration
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
rip start
rip set default-metric 2
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! RIP Interface Configuration. Create a RIP interfaces, and set
! their type to (version II, multicast).
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
rip add interface to-r41
rip add interface to-r42
rip add interface to-r6
rip set interface to-r41 version 2 type multicast
rip set interface to-r42 version 2 type multicast
rip set interface to-r6  version 2 type multicast
```

Importing a Selected Subset of Routes from One RIP Trusted Gateway

Router R1 has several RIP peers. Router R41 has an interface on the network 10.51.0.0. By default, router R41 advertises network 10.51.0.0/16 in its RIP updates. Router R1 would like to import all routes except the 10.51.0.0/16 route from its peer R41.

1. Add the peer 140.1.1.41 to the list of trusted and source gateways.

```
rip add source-gateways 140.1.1.41
rip add trusted-gateways 140.1.1.41
```


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2. Create a RIP import source with the gateway as 140.1.1.41 since we would like to import all routes except the 10.51.0.0/16 route from this gateway.

```
ip-router policy create rip-import-source ripImpSrc144 gateway 140.1.1.41
```

3. Create the Import-Policy, importing all routes except the 10.51.0.0/16 route from gateway 140.1.1.41.

```
ip-router policy import source ripImpSrc144 network all
ip-router policy import source ripImpSrc144 network 10.51.0.0/16 restrict
```

Importing a Selected Subset of Routes from All RIP Peers Accessible Over a Certain Interface

Router R1 has several RIP peers. Router R41 has an interface on the network 10.51.0.0. By default, router R41 advertises network 10.51.0.0/16 in its RIP updates. Router R1 would like to import all routes except the 10.51.0.0/16 route from all its peer which are accessible over interface 140.1.1.1.

1. Create a RIP import source with the interface as 140.1.1.1, since we would like to import all routes except the 10.51.0.0/16 route from this interface.

```
ip-router policy create rip-import-source ripImpSrc140 interface 140.1.1.1
```

2. Create the Import-Policy importing all routes except the 10.51.0.0/16 route from interface 140.1.1.1

```
ip-router policy import source ripImpSrc140 network all
ip-router policy import source ripImpSrc140 network 10.51.0.0/16 restrict
```

18.3.11 Import Policies Example: Importing from OSPF

Due to the nature of OSPF, only the importation of ASE routes may be controlled. OSPF intra-and inter-area routes are always imported into the RS routing table with a preference of 10. If a tag is specified, the import clause will only apply to routes with the specified tag.

It is only possible to restrict the importation of OSPF ASE routes when functioning as an AS border router.

Like the other interior protocols, preference cannot be used to choose between OSPF ASE routes. That is done by the OSPF costs. Routes that are rejected by policy are stored in the table with a negative preference.

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For all examples in this section, refer to the configuration shown in Figure 18-2.

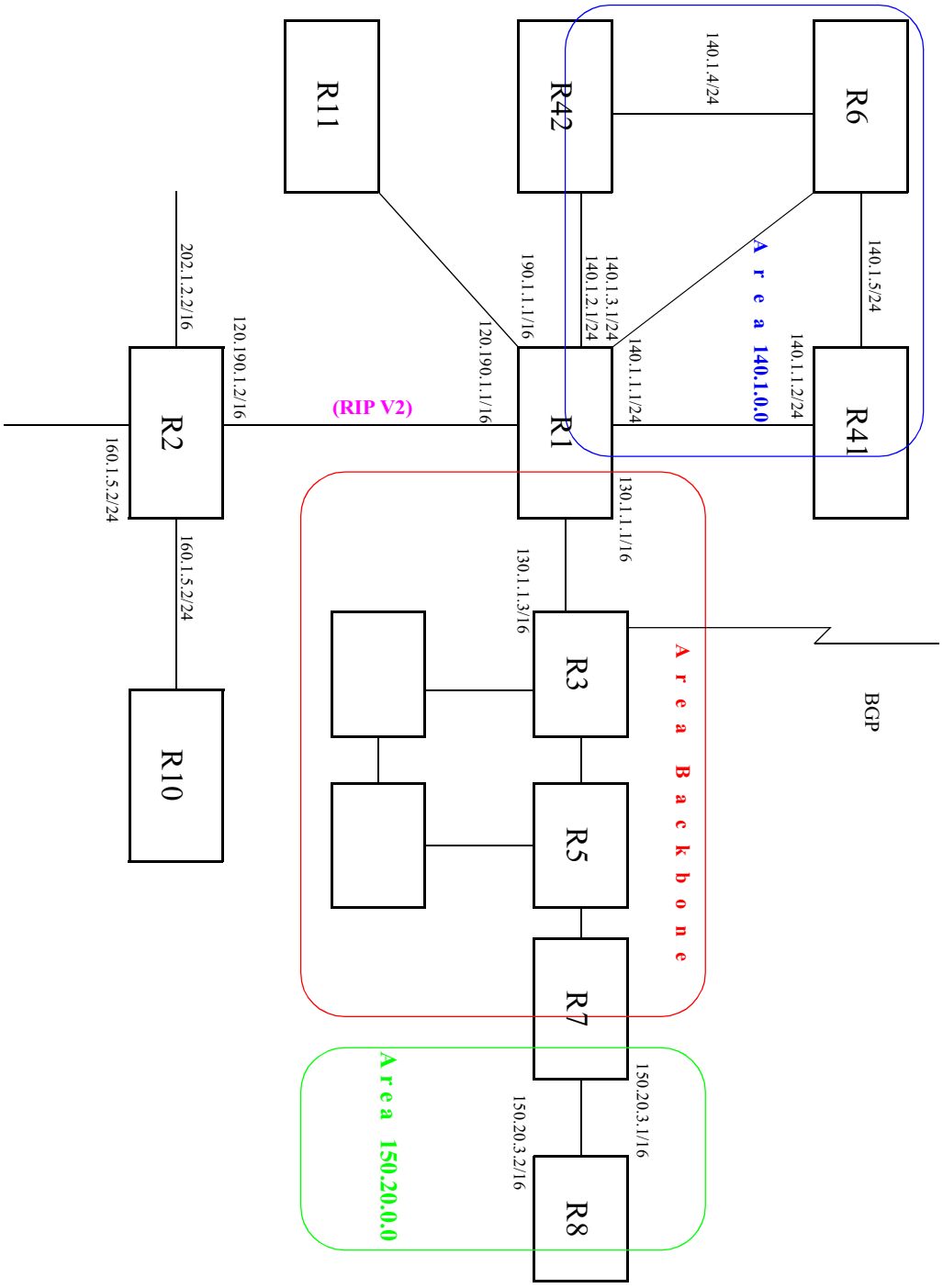

Figure 18-2 Exporting to OSPF

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router

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- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.1.1.2
 ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```

Importing a Selected Subset of OSPF-ASE Routes

1. Create a OSPF import source so that only routes that have a tag of 100 are considered for importation.

```
ip-router policy create ospf-import-source ospfImpSrct100 tag 100
```

2. Create the Import-Policy importing all OSPF ASE routes with a tag of 100 except the default ASE route.

```
ip-router policy import source ospfImpSrct100 network all
ip-router policy import source ospfImpSrct100 network default
restrict
```


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18.3.12 Export Policies Example: Exporting to RIP

Exporting to RIP is controlled by any of protocol, interface or gateway. If more than one is specified, they are processed from most general (protocol) to most specific (gateway).

It is not possible to set metrics for exporting RIP routes into RIP. Attempts to do this are silently ignored.

If no export policy is specified, RIP and interface routes are exported into RIP. If any policy is specified, the defaults are overridden; it is necessary to explicitly specify everything that should be exported.

RIP version 1 assumes that all subnets of the shared network have the same subnet mask so it is only able to propagate subnets of that network. RIP version 2 removes that restriction and is capable of propagating all routes when not sending version 1 compatible updates.

To announce routes which specify a next hop of the loopback interface (i.e. static and internally generated default routes) via RIP, it is necessary to specify the metric at some level in the export policy. Just setting a default metric for RIP is not sufficient. This is a safeguard to verify that the announcement is intended.

For all examples in this section, refer to the configuration shown in Figure 18-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its RIP configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
 interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure a default route through 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route default gateway 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the 135.3.0.0 subnets reachable through
 ! R3.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 135.3.1.0/24 gateway 130.1.1.3
 ip add route 135.3.2.0/24 gateway 130.1.1.3
 ip add route 135.3.3.0/24 gateway 130.1.1.3
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.190.1.2
 ip add route 160.1.5.0/24 gateway 120.190.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip start
 rip set default-metric 2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```


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```
 ! RIP Interface Configuration. Create a RIP interfaces, and set
 ! their type to (version II, multicast).
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip add interface to-r41
 rip add interface to-r42
 rip add interface to-r6
 rip set interface to-r41 version 2 type multicast
 rip set interface to-r42 version 2 type multicast
 rip set interface to-r6  version 2 type multicast
```

Exporting a Given Static Route to All RIP Interfaces

Router R1 has several static routes, of which one is the default route. We would export this default route over all RIP interfaces.

1. Create a RIP export destination since we would like to export routes into RIP.

```
ip-router policy create rip-export-destination ripExpDst
```

2. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

As mentioned above, if no export policy is specified, RIP and interface routes are exported into RIP. If any policy is specified, the defaults are overridden; it is necessary to explicitly specify everything that should be exported.

Since we would also like to export/redistribute RIP and direct routes into RIP, we would also create export-sources for those protocols.

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source since we would like to export direct/interface routes.

```
ip-router policy create direct-export-source directExpSrc
```


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5. Create the export-policy redistributing the statically created default route, and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc network default
ip-router policy export destination ripExpDst source ripExpSrc network all
ip-router policy export destination ripExpDst source directExpSrc network all
```

Exporting a Given Static Route to a Specific RIP Interface

In this case, router R1 would export/redistribute the default route over its interface 140.1.1.1 only.

1. Create a RIP export destination for interface with address 140.1.1.1, since we intend to change the rip export policy only for interface 140.1.1.1.

```
ip-router policy create rip-export-destination ripExpDst141 interface 140.1.1.1
```

2. Create a static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source since we would like to export direct/interface routes.

```
ip-router policy create direct-export-source directExpSrc
```


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5. Create the Export-Policy redistributing the statically created default route, and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst141 source statExpSrc network default
ip-router policy export destination ripExpDst141 source ripExpSrc network all
ip-router policy export destination ripExpDst141 source directExpSrc network all
```

Exporting All Static Routes Reachable Over a Given Interface to a Specific RIP Interface

In this case, router R1 would export/redistribute all static routes accessible through its interface 130.1.1.1 to its RIP-interface 140.1.1.1 only.

1. Create a RIP export destination for interface with address 140.1.1.1, since we intend to change the rip export policy for interface 140.1.1.1

```
ip-router policy create rip-export-destination ripExpDst141 interface 140.1.1.1
```

2. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc130 interface 130.1.1.1
```

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```


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5. Create the Export-Policy, redistributing all static routes reachable over interface 130.1.1.1 and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst141 source statExpSrc130 network all
ip-router policy export destination ripExpDst141 source ripExpSrc network all
ip-router policy export destination ripExpDst141 source directExpSrc network all
```

Exporting Aggregate-Routes into RIP

In the configuration shown in Figure 18-1, suppose you decide to run RIP Version 1 on network 130.1.0.0/16, connecting routers R1 and R3. Router R1 desires to announce the 140.1.1.0/24 and 140.1.2.0/24 networks to router R3. RIP Version 1 does not carry any information about subnet masks in its packets. Thus it would not be possible to announce the subnets (140.1.1.0/24 and 140.1.2.0/24) into RIP Version 1 without aggregating them.

1. Create an Aggregate-Destination which represents the aggregate/summarized route.

```
ip-router policy create aggr-gen-dest aggrDst140 network 140.1.0.0/16
```

2. Create an Aggregate-Source which qualifies the source of the routes contributing to the aggregate. Since in this case, we do not care about the source of the contributing routes, we would specify the protocol as all.

```
ip-router policy create aggr-gen-source allAggrSrc protocol all
```

3. Create the aggregate/summarized route. This command binds the aggregated route with the contributing routes.

```
ip-router policy aggr-gen destination aggrDst140 source allAggrSrc network
    140.1.1.0/24
ip-router policy aggr-gen destination aggrDst140 source allAggrSrc network
    140.1.2.0/24
```

4. Create a RIP export destination for interface with address 130.1.1.1, since we intend to change the rip export policy only for interface 130.1.1.1.

```
ip-router policy create rip-export-destination ripExpDst130 interface 130.1.1.1
```


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5. Create a Aggregate export source since we would to export/redistribute an aggregate/summarized route.

```
ip-router policy create aggr-export-source aggrExpSrc
```

6. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

7. Create a Direct export source since we would like to export Direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy redistributing all (RIP, Direct) routes and the aggregate route 140.1.0.0/16 into RIP.

```
ip-router policy export destination ripExpDst130 source aggrExpSrc network
    140.1.0.0/16
ip-router policy export destination ripExpDst130 source ripExpSrc network all
ip-router policy export destination ripExpDst130 source directExpSrc network all
```

18.3.13 Export Policies Example: Exporting to OSPF

It is not possible to create OSPF intra- or inter-area routes by exporting routes from the RS routing table into OSPF. It is only possible to export from the RS routing table into OSPF ASE routes. It is also not possible to control the propagation of OSPF routes within the OSPF protocol.

There are two types of OSPF ASE routes: type 1 and type 2. The default type is specified by the **`ospf set ase-defaults type 1/2`** command. This may be overridden by a specification in the **`ip-router policy create ospf-export-destination`** command.

OSPF ASE routes also have the provision to carry a tag. This is an arbitrary 32-bit number that can be used on OSPF routers to filter routing information. The default tag is specified by the **`ospf set ase-defaults tag`** command. This may be overridden by a tag specified with the **`ip-router policy create ospf-export-destination`** command.

Interface routes are not automatically exported into OSPF. They have to be explicitly done.

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For all examples in this section, refer to the configuration shown in Figure 18-2.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.1.1.2
 ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```

Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We would export these static routes as type-2 OSPF routes. The interface routes would redistributed as type 1 OSPF routes.

1. Create a OSPF export destination for type-1 routes since we would like to redistribute certain routes into OSPF as type 1 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```


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2. Create a OSPF export destination for type-2 routes since we would like to redistribute certain routes into OSPF as type 2 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

3. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

4. Create a Direct export source since we would like to export interface/direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy for redistributing all interface routes and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
```

Exporting All RIP, Interface & Static Routes to OSPF

Note Also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 18-2, suppose we decide to run RIP Version 2 on network 120.190.0.0/16, connecting routers R1 and R2.

We would like to redistribute these RIP routes as OSPF type-2 routes, and associate the tag 100 with them. Router R1 would also like to redistribute its static routes as type 2 OSPF routes. The interface routes would redistributed as type 1 OSPF routes.

Router R1 would like to redistribute its OSPF, OSPF-ASE, RIP, Static and Interface/Direct routes into RIP.

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1. Enable RIP on interface 120.190.1.1/16.

```
rip add interface 120.190.1.1
rip set interface 120.190.1.1 version 2 type multicast
```

2. Create a OSPF export destination for type-1 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```

3. Create a OSPF export destination for type-2 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

4. Create a OSPF export destination for type-2 routes with a tag of 100.

```
ip-router policy create ospf-export-destination ospfExpDstType2t100 type 2 tag 100
    metric 4
```

5. Create a RIP export source.

```
ip-router policy export destination ripExpDst source ripExpSrc network all
```

6. Create a Static export source.

```
ip-router policy create static-export-source statExpSrc
```


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7. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy for redistributing all interface, RIP and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
ip-router policy export destination ospfExpDstType2t100 source ripExpSrc network all
```

9. Create a RIP export destination.

```
ip-router policy create rip-export-destination ripExpDst
```

10. Create OSPF export source.

```
ip-router policy create ospf-export-source ospfExpSrc type OSPF
```

11. Create OSPF-ASE export source.

```
ip-router policy create ospf-export-source ospfAseExpSrc type OSPF-ASE
```

12. Create the Export-Policy for redistributing all interface, RIP, static, OSPF and OSPF-ASE routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc network all
ip-router policy export destination ripExpDst source ripExpSrc network all
ip-router policy export destination ripExpDst source directExpSrc network all
ip-router policy export destination ripExpDst source ospfExpSrc network all
ip-router policy export destination ripExpDst source ospfAseExpSrc network all
```


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19 MULTICAST ROUTING CONFIGURATION

Multicast routing on the RS is supported through DVMRP and IGMP. IGMP is used to determine host membership on directly attached subnets. DVMRP is used to determine forwarding of multicast traffic between RS's.

This chapter:

- Provides an overview of the RS's implementation of the Internet Group Management Protocol (IGMP)
- Provides an overview of the RS's implementation of the Distance Vector Multicast Routing Protocol (DVMRP)
- Discusses configuring DVMRP routing on the RS
- Discusses configuring IGMP on the RS

19.1 IGMP OVERVIEW

The RS supports IGMP Version 2.0 as defined in RFC 2236. IGMP is run on a per-IP interface basis. An IP interface can be configured to run just IGMP and not DVMRP. Since multiple physical ports (VLANs) can be configured with the same IP interface on the RS, IGMP keeps track of multicast host members on a per-port basis. Ports belonging to an IP VLAN without any IGMP membership will not be forwarded any multicast traffic.

The RS allows per-interface control of the host query interval and response time. Query interval defines the time between IGMP queries. Response time defines the time the RS will wait for host responses to IGMP queries. The RS can be configured to deny or accept group membership filters.

19.2 DVMRP OVERVIEW

DVMRP is an IP multicast routing protocol. On the RS, DVMRP routing is implemented as specified in the **`draft-ietf-idmr-dvmrp-v3-06.txt`** file, which is an Internet Engineering Task Force (IETF) document. The RS's implementation of DVMRP supports the following:

- The mtrace utility, which racks the multicast path from a source to a receiver.
- Generation identifiers, which are assigned to DVMRP whenever that protocol is started on a router.
- Pruning, which is an operation DVMRP routers perform to exclude interfaces not in the shortest path tree.

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DVMRP uses the Reverse Path Multicasting (RPM) algorithm to perform pruning. In RPM, a source network rather than a host is paired with a multicast group. This is known as an (S,G) pair. RPM permits the RS to maintain multiple (S,G) pairs.

On the RS, DVMRP can be configured on a per-interface basis. An interface does not have to run both DVMRP and IGMP. You can start and stop DVMRP independently from other multicast routing protocols. IGMP starts and stops automatically with DVMRP. The RS supports up to 64 multicast interfaces.

To support backward compatibility on DVMRP interfaces, you can configure the router expire time and prune time on each RS DVMRP interface. This lets it work with older versions of DVMRP.

You can use threshold values and scopes to control internetwork traffic on each DVMRP interface. Threshold values determine whether traffic is either restricted or not restricted to a subnet, site, or region. Scopes define a set of multicast addresses of devices to which the RS can send DVMRP data. Scopes can include only addresses of devices on a company's internal network and cannot include addresses that require the RS to send DVMRP data on the Internet. The RS also allows control of routing information exchange with peers through route filter rules.

You can also configure tunnels on RS DVMRP interfaces. A tunnel is used to send packets between routers separated by gateways that do not support multicast routing. A tunnel acts as a virtual network between two routers running DVMRP. A tunnel does not run IGMP. The RS supports a maximum of eight tunnels.

Note Tunnel traffic is not optimized on a per-port basis, and it goes to all ports on an interface, even though IGMP keeps per-port membership information. This is done to minimize CPU overload for tunneled traffic.

19.3 CONFIGURING IGMP

You configure IGMP on the RS by performing the following configuration tasks:

- Creating IP interfaces
- Setting global parameters that will be used for all the interfaces on which DVMRP is enabled
- Configuring IGMP on individual interfaces. You do so by enabling and disabling IGMP on interfaces and then setting IGMP parameters on the interfaces on which IGMP is enabled
- Start the multicast routing protocol (i.e., DVMRP)

19.3.1 Configuring IGMP on an IP Interface

By default IGMP is disabled on the RS.

To enable IGMP on an interface, enter the following command in Configure mode:

Enable IGMP on an interface.	**igmp enable interface** <*name/ipAddr*>

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19.3.2 Configuring IGMP Query Interval

You can configure the RS with a different IGMP Host Membership Query time interval. The interval you set applies to all ports on the RS. The default query time interval is 125 seconds.

To configure the IGMP host membership query time interval, enter the following command in Configure mode:

Configure the IGMP host membership query time interval.	**igmp set queryinterval** <*num*>

19.3.3 Configuring IGMP Response Wait Time

You can configure the RS with a wait time for IGMP Host Membership responses which is different from the default. The wait time you set then applies to all ports on the RS. The default response time is 10 seconds.

To configure the host response wait time, enter the following command in Configure mode:

Configure the IGMP host response wait time.	**igmp set responsetime** <*num*>

19.3.4 Configuring Per-Interface Control of IGMP Membership

You can configure the RS to control IGMP membership on a per-interface basis. An interface can be configured to be allowed or not allowed membership to a particular group.

To configure the per-interface membership control, enter the following commands in Configure mode:

Allow a host group membership to a specific group.	**igmp set interface** <*name/ip-addr*> **allowed-groups** <*ip-addr/subnet mask*>
Disallow a host group membership to a specific group.	**igmp set interface** <*name/ip-addr*> **not-allowed-groups** <*ip-addr/subnet mask*>

19.3.5 Configuring Static IGMP Groups

If IGMP is enabled on an interface, at least one group member needs to be present on the interface for the RS to retain the group on its list of multicast group memberships for the interface. You can configure a static IGMP group for an interface; a static group can exist without any group members present on the interface.

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To configure a static IGMP group on an interface, enter the following command in Configure mode:

Configure a static IGMP group on an interface.	**igmp join group** <*ip-addr/subnet mask*> **interface** <*name/ip-addr*>

19.4 CONFIGURING DVMRP

You configure DVMRP routing on the RS by performing the following DVMRP-configuration tasks:

- Creating IP interfaces
- Setting global parameters that will be used for all the interfaces on which DVMRP is enabled
- Configuring DVMRP on individual interfaces. You do so by enabling and disabling DVMRP on interfaces and then setting DVMRP parameters on the interfaces on which DVMRP is disabled
- Defining DVMRP tunnels, which IP uses to send multicast traffic between two end points

19.4.1 Starting and Stopping DVMRP

DVMRP is disabled by default on the RS.

To start or stop DVMRP, enter one of the following commands in Configure mode:

Start DVMRP.	**dvmrp start**
Stop DVMRP.	**no dvmrp start**

19.4.2 Configuring DVMRP on an Interface

DVMRP can be controlled/configured on per-interface basis. An interface does not have to run both DVMRP and IGMP together. DVMRP can be started or stopped; IGMP starts and stops automatically with DVMRP.

To enable IGMP on an interface, enter the following command in the Configure mode:

Enable DVMRP on an interface.	**dvmrp enable interface** <*ipAddr*>|<*interface-name*>

19.4.3 Configuring DVMRP Parameters

In order to support backward compatibility, DVMRP neighbor timeout and prune time can be configured on a per-interface basis. The default neighbor timeout is 35 seconds. The default prune time is 7200 seconds (2 hours).

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To configure neighbor timeout or prune time, enter one of the following commands in Configure mode:

Configure the DVMRP neighbor timeout.	**dvmrp set interface** <*ip-addr*> **neighbor-timeout** <*number*>
Configure the DVMRP prune time.	**dvmrp set interface** <*ip-addr*> **prunetime** <*number*>

19.4.4 Configuring the DVMRP Routing Metric

You can configure the DVMRP routing metric associated with a set of destinations for DVMRP reports. The default metric is 1.

To configure the DVMRP routing metric, enter the following command in Configure mode:

Configure the DVMRP routing metric.	**dvmrp set interface** <*ip-addr*> **metric** <*number*>

19.4.5 Configuring DVMRP TTL & Scope

For control over internet traffic, per-interface control is allowed through Scopes and TTL thresholds.

The TTL value controls whether packets are forwarded from an interface. The following are conventional guidelines for assigning TTL values to a multicast application and their corresponding RS setting for DVMRP threshold:

TTL = 1	Threshold = 1	Application restricted to subnet
TTL < 16	Threshold = 16	Application restricted to a site
TTL < 64	Threshold = 64	Application restricted to a region
TTL < 128	Threshold = 128	Application restricted to a continent
TTL = 255		Application not restricted

To configure the TTL Threshold, enter the following command in Configure mode:

Configure the TTL Threshold.	**dvmrp set interface** <*ip-addr*> **threshold** <*number*>

TTL thresholding is not always considered useful. There is another approach of a range of multicast addresses for “administrative” scoping. In other words, such addresses would be usable within a certain administrative scope, a corporate network, for instance, but would not be forwarded across the internet. The range from 239.0.0.0 through 239.255.255.255 is being reserved for administratively scoped applications. Any organization can currently assign this range of addresses and the packets will not be sent out of the organization. In addition, multiple scopes can be defined on per-interface basis.

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To prevent the RS from forwarding any data destined to a scoped group on an interface, enter the following command in the Configure mode:

Configure the DVMRP scope.	**dvmrp set interface** <*ip-addr*> **scope** <*ip-addr/mask*>

19.4.6 Configuring a DVMRP Tunnel

The RS supports DVMRP tunnels to the MBONE (the multicast backbone of the Internet). You can configure a DVMRP tunnel on a router if the other end is running DVMRP. The RS then sends and receives multicast packets over the tunnel. Tunnels are CPU-intensive; they are not switched directly through the RS's multitasking ASICs.

DVMRP tunnels need to be created before being enabled. Tunnels are recognized by the tunnel name. Once a DVMRP tunnel is created, you can enable DVMRP on the interface. The RS supports a maximum of eight tunnels.

To configure a DVMRP tunnel, enter the following command in Configure mode:

Configure a DVMRP tunnel to MBONE.	**dvmrp create tunnel** <*string*> **local** <*ip-addr*> **remote** <*ip-addr*>

You can also control the rate of DVMRP traffic in a DVMRP tunnel. The default rate is 500 Kbps.

To control the rate of DVMRP traffic, enter the following command in Configure mode:

Configure the rate in a DVMRP tunnel.	**dvmrp set interface** <*ip-addr*> **rate** <*number*>

19.5 MONITORING IGMP & DVMRP

You can monitor IGMP and DVMRP information on the RS.

To display IGMP and DVMRP information, enter the following commands in the Enable mode.

Show all interfaces running DVMRP. Also shows the neighbors on each interface.	**dvmrp show interface**
Display DVMRP routing table.	**dvmrp show routes**
Shows all the interfaces and membership details running IGMP.	**igmp show interface**
Shows all IGMP group memberships on a port basis.	**igmp show memberships**
Show all IGMP timers.	**igmp show timers**

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Show information about multicasts registered by IGMP.	**l2-tables show igmp-mcast-registration**
Show IGMP status on a VLAN.	**l2-tables show vlan-igmp-status**
Show all multicast Source, Group entries.	**mulitcast show cache**
Show all interfaces running multicast protocols (IGMP, DVMRP).	**multicast show interfaces**
Show all multicast routes.	**multicast show mroutes**

19.6 CONFIGURATION EXAMPLE

The following is a sample RS configuration for DVMRP and IGMP. Seven subnets are created. IGMP is enabled on 4 IP interfaces. The IGMP query interval is set to 30 seconds. DVMRP is enabled on 5 IP interfaces. IGMP is not running on “downstream” interfaces.

```
! Create VLANS.
!
vlan create upstream ip
vlan add ports et.5.3,et.5.4 to upstream
!
! Create IP intefaces
!
interface create ip mls15 address-netmask 172.1.1.10/24 port et.5.8
interface create ip company address-netmask 207.135.89.64/25 port et.5.1
interface create ip test address-netmask 10.135.89.10/25 port et.1.8
interface create ip rip address-netmask 190.1.0.1 port et.1.4
interface create ip mbone address-netmask 207.135.122.11/29 port et.1.1
interface create ip downstream address-netmask 10.40.1.10/24 vlan upstream
!
! Enable IGMP interfaces.
!
igmp enable interface 10.135.89.10
igmp enable interface 172.1.1.10
igmp enable interface 207.135.122.11
igmp enable interface 207.135.89.64
!
```


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```
! Set IGMP Query Interval
!
igmp set queryinterval 30
!
! Enable DVMRP
!
dvmrp enable interface 10.135.89.10
dvmrp enable interface 172.1.1.10
dvmrp enable interface 207.135.122.11
dvmrp enable interface 207.135.89.64
dvmrp enable interface 10.40.1.10
!
! Set DVMRP parameters
!
dvmrp set interface 172.1.1.10 neighbor-timeout 200
!
! Start DVMRP
!
dvmrp start
```


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20 IP POLICY-BASED FORWARDING CONFIGURATION

You can configure the RS to route IP packets according to policies that you define. IP policy-based routing allows network managers to engineer traffic to make the most efficient use of their network resources.

IP policies forward packets based on layer-3 or layer-4 header information. You can define IP policies to route packets to a set of next-hop IP addresses based on any combination of the following IP header fields:

- IP protocol
- Source IP address
- Destination IP address
- Source Socket
- Destination Socket
- Type of service

For example, you can set up an IP policy to send packets originating from a certain network through a firewall, while letting other packets bypass the firewall. Sites that have multiple Internet service providers can use IP policies to assign user groups to particular ISPs. You can also create IP policies to select service providers based on various traffic types.

20.1 CONFIGURING IP POLICIES

To implement an IP policy, you first create a profile for the packets to be forwarded using an IP policy. For example, you can create a profile defined as “all telnet packets going from network 9.1.0.0/16 to network 15.1.0.0/16”. You then associate the profile with an IP policy. The IP policy specifies what to do with the packets that match the profile. For example, you can create an IP policy that sends packets matching a given profile to next-hop gateway 100.1.1.1.

Configuring an IP policy consists of the following tasks:

- Defining a profile
- Associating the profile with a policy
- Applying the IP policy to an interface

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20.1.1 Defining an ACL Profile

An ACL profile specifies the criteria packets must meet to be eligible for IP policy routing. You define profiles with the **acl** command. For IP policy routing, the RS uses the packet-related information from the **acl** command and ignores the other fields.

For example, the following **acl** command creates a profile called "prof1" for telnet packets going from network 9.1.0.0 to network 15.1.0.0:

```
rs(config)# acl prof1 permit ip 9.1.0.0/16 15.1.0.0/16 any any telnet 0
```

See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **acl** command.

Note ACLs for non-IP protocols cannot be used for IP policy routing.

20.1.2 Associating the Profile with an IP Policy

Once you have defined a profile with the **acl** command, you associate the profile with an IP policy by entering one or more **ip-policy** statements. An **ip-policy** statement specifies the next-hop gateway (or gateways) where packets matching a profile are forwarded. (See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **ip-policy** command.)

For example, the following command creates an IP policy called "p1" and specifies that packets matching profile "prof1" are forwarded to next-hop gateway 10.10.10.10:

```
rs(config)# ip-policy p1 permit acl prof1 next-hop-list 10.10.10.10
```

You can also set up a policy to prevent packets from being forwarded by an IP policy. For example, the following command creates an IP policy called "p2" that prevents packets matching prof1 from being forwarded using an IP policy:

```
rs(config)# ip-policy p2 deny acl prof1
```

Packets matching the specified profile are forwarded using dynamic routes instead.

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Creating Multi-Statement IP Policies

An IP policy can contain more than one **ip-policy** statement. For example, an IP policy can contain one statement that sends all packets matching a profile to one next-hop gateway, and another statement that sends packets matching a different profile to a different next-hop gateway. If an IP policy has multiple **ip-policy** statements, you can assign each statement a sequence number that controls the order in which they are evaluated. Statements are evaluated from lowest sequence number to highest.

For example, the following commands create an IP policy called "p3", which consists of two IP policy statements. The **ip policy permit** statement has a sequence number of 1, which means it is evaluated before the **ip policy deny** statement, which has a sequence number of 900.

```
rs(config)# ip-policy p3 permit acl prof1 next-hop-list 10.10.10.10 sequence 1
rs(config)# ip-policy p3 deny acl prof2 sequence 900
```

Setting the IP Policy Action

You can use the **action** parameter with the **ip-policy permit** command to specify when to apply the IP policy route with respect to dynamic or statically configured routes. The options of the **action** parameter can cause packets to use the IP policy route first, then the dynamic route if the next-hop gateway specified in the IP policy is unavailable; use the dynamic route first, then the IP policy route; or drop the packets if the next-hop gateway specified in the IP policy is unavailable.

For example, the following command causes packets that match the profile to use dynamic routes first and use the IP policy gateway only if a dynamic route is not available:

```
rs(config)# ip-policy p2 permit acl prof1 action policy-last
```

Setting Load Distribution for Next-Hop Gateways

You can specify up to 16 next-hop gateways in an **ip-policy** statement. If you specify more than one next-hop gateway, you can use the **ip-policy set load-policy** command to control how the load is distributed among them.

By default, each new flow uses the first available next-hop gateway. You can use the **ip-policy set load-policy** command to cause flows to use all the next-hop gateways in the **ip-policy permit** statement sequentially. For example, the following command picks the next gateway in the list for each new flow for policy 'p1':

```
rs(config)# ip-policy p1 set load-policy round-robin
```


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Verifying Next-Hop Gateways

The **ip-policy set pinger on** command can be used to check the availability of next-hop gateways by periodically querying them with ICMP_ECHO_REQUESTS. Only gateways that respond to these requests are used for forwarding packets. For example, the following command checks the availability of next-hop gateways specified in the policy 'p1':

```
rs(config)# ip-policy p1 set pinger on
```

Note Some hosts may have disabled responding to ICMP_ECHO packets. Make sure each next-hop gateway can respond to ICMP_ECHO packets before using this option.

When the **ip-policy set pinger on** command is issued, the RS can verify the state of a next-hop gateway by sending a ping to the gateway at 5-second intervals. If the RS does not receive a reply from a gateway after four ping requests, the gateway is considered to be "down."

If you specify that the RS use TCP connection requests to check the gateway (instead of sending ICMP echo requests), the RS checks that an application session on the gateway can be established by sending a TCP connection request on the configured port of the gateway at 15-second intervals. If the RS does not receive a reply from the gateway after four tries, the application is considered to be "down."

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the gateway or application to be "down."

For example, the following commands cause the RS to check the availability of next-hop gateways for the IP policy 'p1' by pinging every 10 seconds:

```
rs(config)# ip-policy p1 set pinger on
rs(config)# ip-policy set pinger-options p1 ping-int 10
```

You can also have the RS verify the *content* of an application on one or more next-hop gateways. For this type of verification, you specify the following:

- A string that the RS sends to a single gateway or to a group of next-hop gateways. The string can be a simple HTTP command to get a specific HTML page. Or, it can be a command to execute a user-defined CGI script that tests the operation of the application.
- The reply that the application on each gateway sends back that the RS will use to validate the content. In the case where a specific HTML page is retrieved, the reply can be a string that appears on the page, such as "OK." If a CGI script is executed on the gateway, it should return a specific response (for example, "OK") that the RS can verify.

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Application verification, whether a simple TCP handshake or a user-defined action-response check, involves opening and closing a connection to a next-hop gateway. Some applications require specific commands for proper closure of the connection. For example, a connection to an SMTP server application should be closed with the “quit” command. You can configure the RS to send a specific string to close a connection on a server.

The following is an example of how to configure a simple verification check where the RS will issue an HTTP command to retrieve an HTML page and check for the string ‘OK’:

```
rs(config)# ip-policy p1 set pinger-options acv-command “GET /test.html” acv-reply “OK”
read-till index 25
```

20.1.3 Applying an IP Policy to an Interface

After you define the IP policy, it must be applied to an inbound IP interface with the **ip-policy apply** command. Once the IP policy is applied to the interface, packets start being forwarded according to the IP policy. (See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **ip-policy apply** command.)

For example, the following command applies the IP policy ‘p2’ to the interface ‘int2’:

```
rs(config)# ip-policy p2 apply interface int2
```

Applying an IP Policy to Locally Generated Packets

You can apply an IP policy to locally-generated packets (that is, packets generated by the RS). For example, the following command applies the IP policy ‘p2’ to locally-generated packets:

```
rs(config)# ip-policy p2 apply local
```

20.2 IP POLICY CONFIGURATION EXAMPLES

This section presents some examples of IP policy configurations. The following uses of IP policies are demonstrated:

- Routing traffic to different ISPs
- Prioritizing service to customers
- Authenticating users through a firewall
- Firewall load balancing

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20.2.1 Routing Traffic to Different ISPs

Sites that have multiple Internet service providers can create IP policies that cause different user groups to use different ISPs. You can also create IP policies to select service providers based on various traffic types.

In the sample configuration in Figure 20-1, the policy router is configured to divide traffic originating within the corporate network between different ISPs (100.1.1.1 and 200.1.1.1).

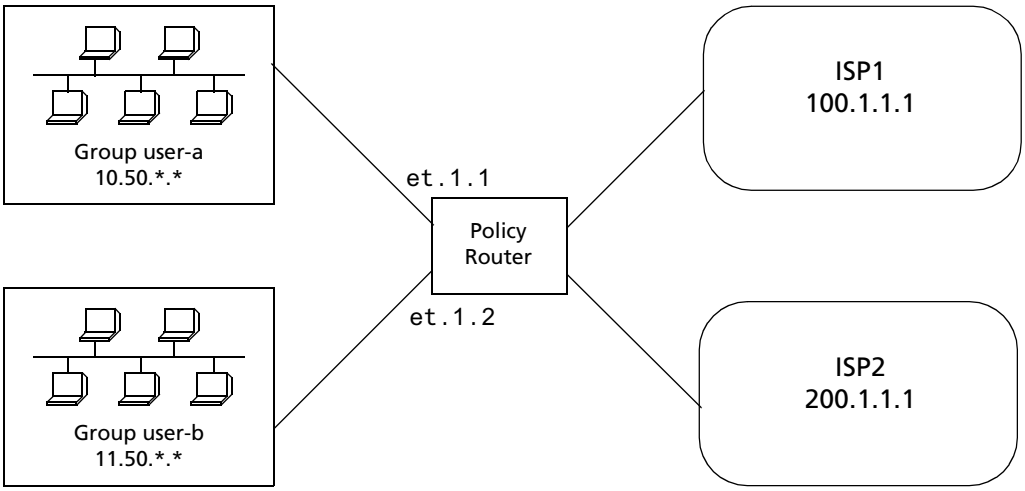

Figure 20-1 Using an IP policy to route traffic to two different ISPs

HTTP traffic originating from network 10.50.0.0 for destination 207.31.0.0/16 is forwarded to 100.1.1.1. Non-HTTP traffic originating from network 10.50.0.0 for destination 207.31.0.0/16 is forwarded to 200.1.1.1. All other traffic is forwarded to 100.1.1.1.

The following is the IP policy configuration for the Policy Router in Figure 20-1:

```
interface create ip user-a address-netmask 10.50.1.1/16 port et.1.1
interface create ip user-b address-netmask 11.50.1.1/16 port et.1.2

acl user-a-http  permit ip 10.50.0.0/16 207.31.0.0/16 any http 0
acl user-a  permit ip 10.50.0.0/16 207.31.0.0/16 any any 0
acl user-b  permit ip 11.50.0.0/16 any any any 0

ip-policy net-a permit acl user-a-http next-hop-list 100.1.1.1 action policy-first
sequence 20

ip-policy net-a permit acl user-a next-hop-list 200.1.1.1 action policy-only
sequence 25

ip-policy net-a apply interface user-a

ip-policy net-b permit acl user-b next-hop-list 200.1.1.1 action policy-first

ip-policy net-b apply interface user-b
```


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20.2.2 Prioritizing Service to Customers

An ISP can use policy-based routing on an access router to supply different customers with different levels of service. The sample configuration in Figure 20-2 shows an RS using an IP policy to classify customers and route traffic to different networks based on customer type.

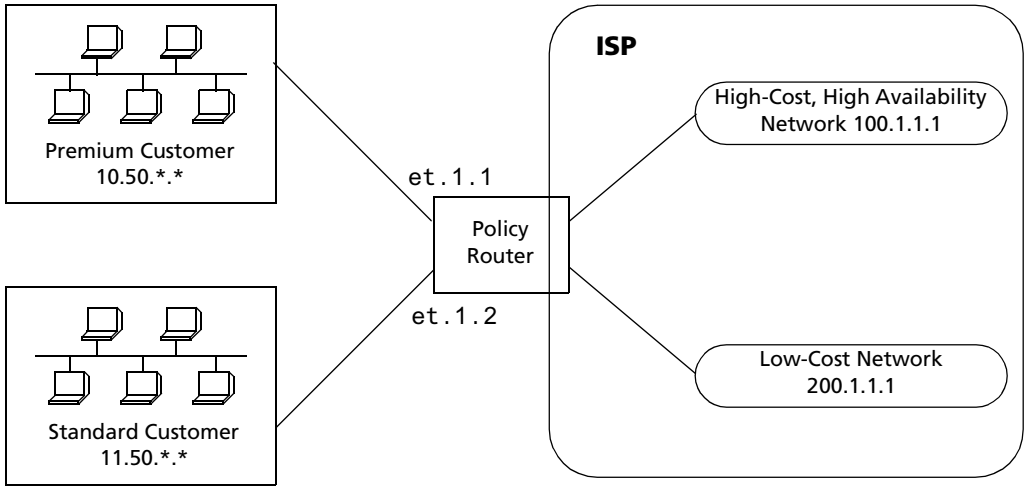

Figure 20-2 Using an IP policy to prioritize service to customers

Traffic from the premium customer is load balanced across two next-hop gateways in the high-cost, high-availability network. If neither of these gateways is available, then packets are forwarded based on dynamic routes learned via routing protocols.

Traffic from the standard customer always uses one gateway (200.1.1.1). If for some reason that gateway is not available, packets from the standard customer are dropped.

The following is the IP policy configuration for the Policy Router in Figure 20-2:

```
interface create ip premium-customer address-netmask 10.50.1.1/16 port et.1.1

interface create ip standard-customer address-netmask 11.50.1.1/16 port et.1.2

acl premium-customer permit ip 10.50.0.0/16 any any any 0
acl standard-customer   permit ip 11.50.0.0/16 any any any 0

ip-policy p1 permit acl premium-customer next-hop-list "100.1.1.1
200.1.1.1" action policy-first sequence 20

ip-policy apply interface premium-customer

ip-policy p2 permit acl standard-customer next-hop-list 200.1.1.1 action
policy-only sequence 30

ip-policy apply interface standard-customer
```


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20.2.3 Authenticating Users through a Firewall

You can define an IP policy that authenticates packets from certain users via a firewall before accessing the network. If, for some reason the firewall is not responding, the packets to be authenticated are dropped. Figure 20-3 illustrates this kind of configuration.

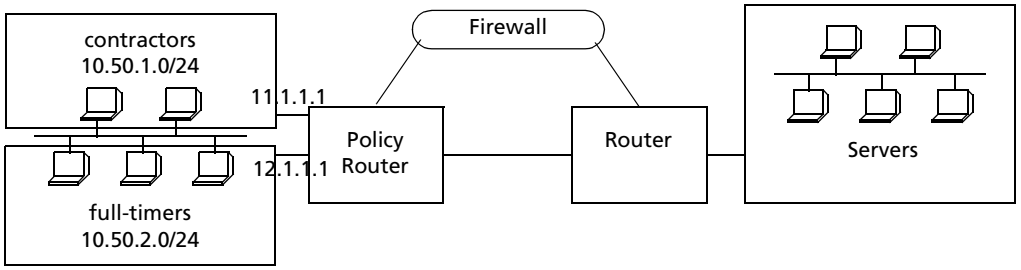

Figure 20-3 Using an IP policy to authenticate users through a firewall

Packets from users defined in the “contractors” group are sent through a firewall. If the firewall cannot be reached packets from the contractors group are dropped. Packets from users defined in the “full-timers” group do not have to go through the firewall.

The following is the IP policy configuration for the Policy Router in Figure 20-3:

```
interface create ip mls0 address-netmask 10.50.1.1/16 port et.1.1

acl contractors permit ip 10.50.1.0/24 any any any 0
acl full-timers permit ip 10.50.2.0/24 any any any 0

ip-policy access permit acl contractors next-hop-list 11.1.1.1 action policy-only
ip-policy access permit acl full-timers next-hop-list 12.1.1.1 action policy-first
ip-policy access apply interface mls0
```


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20.2.4 Firewall Load Balancing

Figure 20-4 shows a simplified example of firewall load balancing. This example shows how to provide protection from a complete firewall failure, but it does not show how to protect against asymmetrical paths if a single link failure occurs.

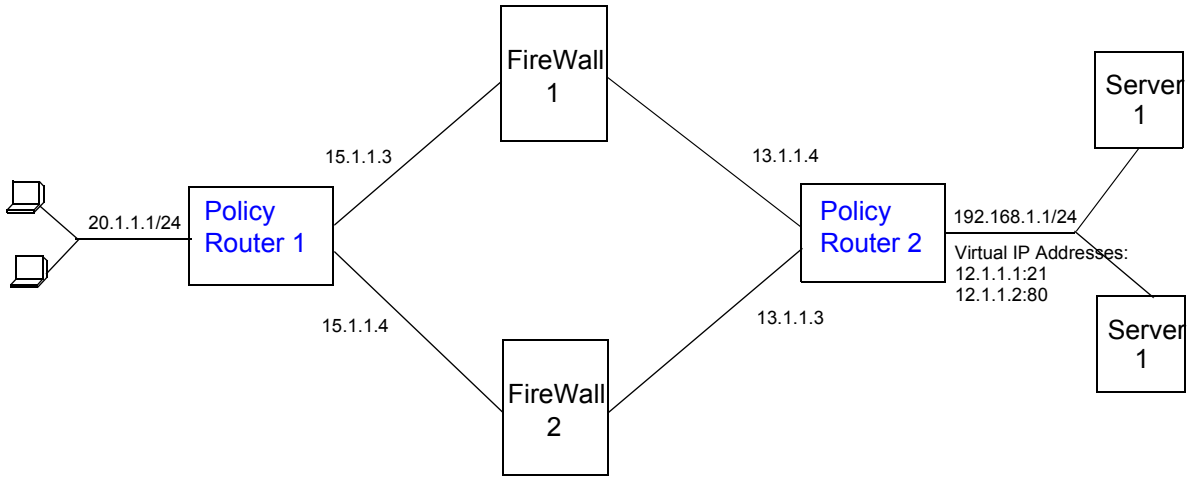

Figure 20-4 Firewall load balancing example

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On Policy Router 1, an ACL profile allows traffic from the clients to the virtual IP addresses of the server (12.1.1.0/24). IP policy configuration will distribute the traffic across the two next hops (the firewalls) based on a hashing of the *source* IP address (the client's address, as provided by DHCP). The following is the configuration for Policy Router 1 in Figure 20-4.

```
! Create client VLAN
vlan create vClient ip id 10
vlan add ports et.1.1 to vClient
vlan add ports et.1.2 to vClient
vlan add ports et.1.3 to vClient
vlan add ports et.1.4 to vClient
! Create Firewall VLAN
vlan create vFirewall ip id 20
vlan add ports et.2.1 to vFirewall
vlan add ports et.2.2 to vFirewall
! Create interfaces
interface create ip iClient address-netmask 20.1.1.1/24 vlan vClient
interface create ip iFirewall address-netmask 15.1.1.1/24 vlan vFirewall
! Create ACL to allow client traffic to pass to server VIPs
acl AclToLB permit ip any 12.1.1.0/24 any any
! Configure IP policy
ip-policy polToLB permit acl AclToLB next-hop-list “15.1.1.3 15.1.1.4” action
policy-only
ip-policy PolToLB apply interface iClient
ip-policy PolToLB set load-policy ip-hash sip
ip-policy PolToLB set pinger on
! Configure DHCP server to provide clients with IP address pool
dhcp dClient define pool 20.1.1.10-20.1.1.100
dhcp dClient define parameters gateway 20.1.1.1 address-netmask 20.1.1.0/24
```


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On Policy Router 2, load balancing groups an ACL profile allows traffic to pass to the clients. IP policy configuration will distribute the traffic across the two next hops (the firewalls) based on a hashing of the *destination* IP address (the client's address). The following is the configuration for Policy Router 2 in Figure 20-4.

```
! Create server VLAN
vlan create vServices ip id 10
vlan add ports et.1.1 to vServices
vlan add ports et.1.2 to vServices
vlan add ports et.1.3 to vServices
vlan add ports et.1.4 to vServices
! Create Firewall VLAN
vlan create vFirewall ip id 20
vlan add ports et.2.1 to vFirewall
vlan add ports et.2.2 to vFirewall
! Create interfaces
interface create ip iServices address-netmask 192.168.1.1/24 vlan vServices
interface create ip iFirewall address-netmask 13.1.1.1/24 vlan vFirewall
! Create ACL to allow server traffic to pass to clients
acl AclToClient permit ip any any any any
! Configure IP policy
ip-policy polToClient permit acl AclToClient next-hop-list “13.1.1.3 13.1.1.4”
action policy-only
ip-policy PolToClient apply interface iServices
ip-policy PolToClient set load-policy ip-hash sip
ip-policy PolToClient set pinger on
! Configure load balancing group for FTP on servers
load-balance create group-name MyFtp virtual-ip 12.1.1.1 virtual-port 21 protocol
tcp
load-balance add host to group 192.168.1.3 port 21 group-name MyFtp
load-balance add host to group 192.168.1.4 port 21 group-name MyFtp
! Configure load balancing group for HTML on servers
load-balance create group-name MyWeb virtual-ip 12.1.1.2 virtual-port 80 protocol
tcp
load-balance add host to group 192.168.1.3 port 80 group-name MyWeb
load-balance add host to group 192.168.1.4 port 80 group-name MyWeb
```

Note Although the configuration of the firewall devices are not shown here, you need to ensure that services are allowed to pass through the firewall while providing site security.

20.3 MONITORING IP POLICIES

The **ip-policy show** command reports information about active IP policies, including profile definitions, policy configuration settings, and next-hop gateways. The command also displays statistics about packets that have matched an IP policy statement as well as the number of packets that have been forwarded to each next-hop gateway.

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For example, to display information about an active IP policy called “p1”, enter the following command in Enable mode:

```
rs# ip-policy show policy-name p1

-------------------------------------------------------------------------------
IP Policy name     : p1 ❶
Applied Interfaces : int1  ❷
Load Policy        : first available  ❸

❹               ❺                ❻               ❼        ❽        ❾  ❿
ACL          Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS Prot
---          --------------     -------------      --------- --------- --- ----
prof1        9.1.1.5/32         15.1.1.2           any       any         0 IP
prof2        2.2.2.2/32         anywhere           any       any         0 IP
everything   anywhere           anywhere           any       any         0 IP

                                                      Next Hop Information
                                                      --------------------
 ⓫    ⓬     ⓭          ⓮    ⓯                          ⓰             ⓱   ⓲
Seq   Rule   ACL        Cnt Action                   Next Hop        Cnt Last
---   ----   --------   --- -----------              --------        --- ----
10    permit prof1      0   Policy Only              11.1.1.2        0   Dwn
20    permit prof2      0   Policy Last              1.1.1.1         0   Dwn
                                                     2.2.2.2         0   Dwn
                                                     3.3.3.3         0   Dwn
999   permit everything 0   Policy Only              drop            N/A N/A
65536 deny   deny       0   N/A                      normal fwd      N/A N/A
⓳
```

Legend:

1. The name of the IP policy.
2. The interface where the IP policy was applied.
3. The load distribution setting for IP-policy statements that have more than one next-hop gateway; either first available (the default) or round-robin.
4. The names of the profiles (created with an **`acl`** statement) associated with this IP policy.
5. The source address and filtering mask of this flow.
6. The destination address and filtering mask of this flow.
7. For TCP or UDP, the number of the source TCP or UDP port.
8. For TCP or UDP, the number of the destination TCP or UDP port.
9. The TOS value in the packet.
10. The protocol of this profile (IP, ICMP, TCP UDP).
11. The sequence in which the statement is evaluated. IP policy statements are listed in the order they are evaluated (lowest sequence number to highest).
12. The rule to apply to the packets matching the profile: either permit or deny
13. The name of the profile (ACL) of the packets to be forwarded using an IP policy.

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14. The number of packets that have matched the profile since the IP policy was applied (or since the **`ip-policy clear`** command was last used)
15. The method by which IP policies are applied with respect to dynamic or statically configured routes; possible values are Policy First, Policy Only, or Policy Last.
16. The list of next-hop gateways in effect for the policy statement.
17. The number of packets that have been forwarded to this next-hop gateway.
18. The state of the link the last time an attempt was made to forward a packet; possible values are up, down, or N/A.
19. Implicit deny rule that is always evaluated last, causing all packets that do not match one of the profiles to be forwarded normally (with dynamic routes).

See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **`ip-policy show`** command.

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21 NETWORK ADDRESS TRANSLATION CONFIGURATION

Network Address Translation (NAT) allows an IP address used within one network to be translated into a different IP address used within another network. NAT is often used to map addresses used in a private, local intranet to one or more addresses used in the public, global Internet. NAT provides the following benefits:

- Limits the number of IP addresses used for private intranets that are required to be registered with the Internet Assigned Numbers Authority (IANA).
- Conserves the number of global IP addresses needed by a private intranet (for example, an entity can use a single IP address to communicate on the Internet).
- Maintains privacy of local networks, as internal IP addresses are hidden from public view.

With NAT, the local network is designated the *inside* network and the global Internet is designated the *outside* network. In addition, the RS supports Port Address Translation (PAT) for either static or dynamic address bindings.

The RS allows you to create the following NAT address bindings:

- Static, one-to-one binding of inside, local address or address pool to outside, global address or address pool. A static address binding does not expire until the command that defines the binding is negated. IP addresses defined for static bindings cannot be reassigned. For static address bindings, PAT allows TCP or UDP port numbers to be translated along with the IP addresses.
- Dynamic binding between an address from a pool of local addresses to an address from a pool of outside addresses. With dynamic address binding, you define local and global address pools from which the addresses bindings can be made. IP addresses defined for dynamic binding are reassigned whenever they become free. For dynamic address bindings, PAT allows port address translation if no addresses are available from the global address pool. PAT allows port address translation for each address in the global pool. The ports are dynamically assigned between the range of 1024 to 4999. Hence, you have about 4,000 ports per global IP address.

  Dynamic bindings are removed automatically when the flow count goes to zero. At this point, the corresponding port (if PAT enabled) or the global IP address is freed and can be reused the next time. Although there are special cases like FTP where the flows are not installed for the control path, the binding will be removed only by the dynamic binding timeout interval.

21.1 CONFIGURING NAT

The following are the steps in configuring NAT on the RS:

1. Setting the NAT interfaces to be “inside” or “outside.”
2. Setting the NAT rules (static or dynamic).

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21.1.1 Setting Inside and Outside Interfaces

When NAT is enabled, address translation is only applied to those interfaces which are defined to NAT as “inside” or “outside” interfaces. NAT only translates packets that arrive on a defined inside or outside interface.

To specify an interface as inside (local) or outside (global), enter the following command in Configure mode.

Define an interface as inside or outside for NAT.	**`nat set interface`** <*InterfaceName*> **`inside|outside`**

21.1.2 Setting NAT Rules

Static

You create NAT static bindings by entering the following command in Configure mode.

Enable NAT with static address binding.	**`nat create static protocol ip|tcp|udp local-ip`** <*local-ip-add/address range*> **`global-ip`** <*global-ip-add/address range*> **`[local-port`** <*tcp/udp local-port*>**`|any] [global-port`** <*tcp/udp global-port*>**`|any]`**

Dynamic

You create NAT dynamic bindings by entering the following command in Configure mode.

Enable NAT with dynamic address binding.	**`nat create dynamic local-acl-pool`** <*local-acl*> **`global-pool`** <*ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask*> **`[matches-interface`** <*interface*>**`] [enable-ip-overload]`**

For dynamic address bindings, you define the address pools with previously-created ACLs. You can also specify the **`enable-port-overload`** parameter to allow PAT.

21.2 FORCING FLOWS THROUGH NAT

If a host on the outside global network knows an inside local address, it can send a message directly to the inside local address. By default, the RS will route the message to the destination. You can force *all* flows between the inside local pool and the outside global network to be translated. This prevents a host on the outside global network from being allowed to send messages directly to any address in the local address pool.

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You force address translation of all flows to and from the inside local pool by entering the following command in Configure mode.

Force all flows to and from local address pool to be translated.	**nat set secure-plus on|off**

21.3 MANAGING DYNAMIC BINDINGS

As mentioned previously, dynamic address bindings expire only after a period of non-use or when they are manually deleted. The default timeout for dynamic address bindings is 1440 minutes (24 hours). You can manually delete dynamic address bindings for a specific address pool or delete all dynamic address bindings.

To set the timeout for dynamic address bindings, enter the following command in Configure mode.

Set timeout for dynamic address bindings.	**nat set dynamic-binding-timeout** <*minutes*> **|disable**

To flush dynamic address bindings, enter the following command in Enable mode.

Flush all dynamic address bindings.	**nat flush-dynamic-binding all**
Flush dynamic address bindings based on local and global ACL pools.	**nat flush-dynamic-binding pool-specified local-acl-pool** <*local-acl*> **global-pool** <*ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask*>
Flush dynamic address bindings based on binding type.	**nat flush-dynamic-binding type-specified dynamic|overloaded-dynamic**
Flush dynamic address bindings based on application.	**nat flush-dynamic-binding owner-specified dns|ftp-control|ftp-data**

21.4 NAT AND DNS

NAT can translate an address that appears in a Domain Name System (DNS) response to a name or inverse lookup. For example, if an outside host sends a name lookup to an inside DNS server, the inside DNS server can respond with a local IP address, which NAT translates to a global address.

To enable NAT DNS translation, enter the following command in Configure mode:

```
nat set dns-translation-state enable
```


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You create NAT dynamic bindings for DNS by entering the following command in Configure mode.

Enable NAT with dynamic address binding for DNS query/reply.	**nat create dynamic local-acl-pool** *<outside-local-acl>* **global-pool** *<ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask>*

DNS packets that contain addresses that match the ACL specified by **outside-local-acl-pool** are translated using local addresses allocated from **inside-global-pool**.

The default timeout for DNS dynamic address bindings is 30 minutes. You can change this timeout by entering the following command in Configure mode:

Specify the timeout for DNS bindings.	**nat set dns-session-timeout** *<minutes>*

21.5 NAT AND ICMP PACKETS

NAT translates addresses embedded in the data portion of the following types of ICMP error messages:

- Destination unreachable (type 3)
- Source quench (type 4)
- Redirect (type 5)
- Time exceeded (type 11)
- Parameter problem (type 12)

21.6 NAT AND FTP

File Transfer Protocol (FTP) packets require special handling with NAT, because the FTP PORT command packets contain IP address information within the data portion of the packet. It is therefore important for NAT to know which control port is used for FTP (the default is port 21) and the timeout for the FTP session (the default is 30 minutes). If FTP packets will arrive on a different port number, you need to specify that port to NAT.

To define FTP parameters to NAT, enter the following commands in Configure mode.

Specify the FTP control port.	**nat set ftp-control-port** *<port number>*
Specify the FTP session timeout.	**nat set ftp-session-timeout** *<minutes>*

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If PAT is enabled, NAT checks packets for the FTP PORT command. If a packet is to be translated (as determined by the ACL specified for the dynamic address binding), NAT creates a dynamic binding for the PORT command. An outside host will only see a global IP address in an FTP response and not the local IP address.

21.7 MONITORING NAT

To display NAT information, enter the following command in Enable mode.

Display NAT information.	**nat show [translations all|**<*type*>**] [timeouts] [statistics]**

21.8 CONFIGURATION EXAMPLES

This section shows examples of NAT configurations.

21.8.1 Static Configuration

The following example configures a static address binding for inside address 10.1.1.2 to outside address 192.50.20.2:

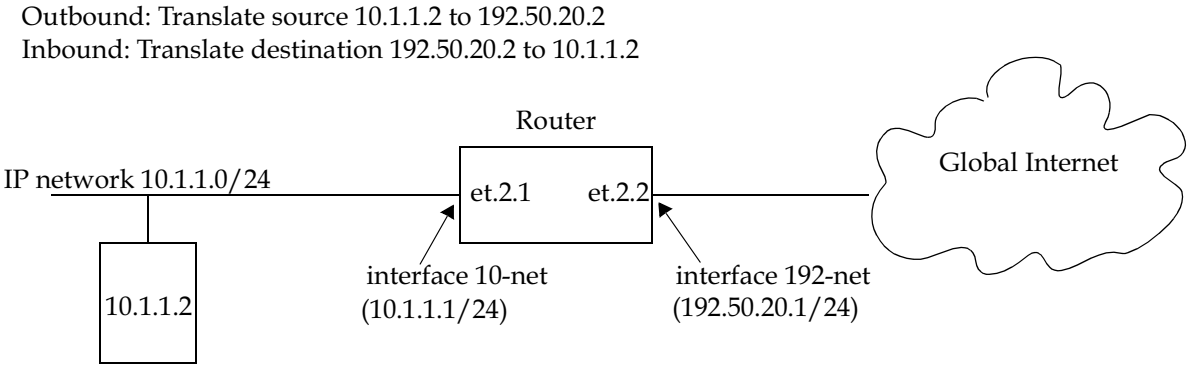

Figure 21-1 Static address binding configuration

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```


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2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT static rules:

```
nat create static protocol ip local-ip 10.1.1.2 global-ip 192.50.20.2
```

Using Static NAT

Static NAT can be used when the local and global IP addresses are to be bound in a fixed manner. These bindings never get removed nor time out until the static NAT command itself is negated. Static binding is recommended when you have a need for a permanent type of binding.

The other use of static NAT is when the out to in traffic is the first to initialize a connection, i.e., the first packet is coming from outside to inside. This could be the case when you have a server in the local network and clients located remotely. Dynamic NAT would not work for this case as bindings are always created when an in to out Internet connection occurs. A typical example is a web server inside the local network, which could be configured as follows:

```
nat create static protocol tcp local-ip 10.1.1.2 global-ip 192.50.20.2 local-port 80
global-port 80
```

This server, 10.1.1.2, is advertised as 192.50.20.2 to the external network.

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21.8.2 Dynamic Configuration

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside address 192.50.20.0/24:

Outbound: Translate source pool 10.1.1.0/24 to global pool 192.50.20.0/24

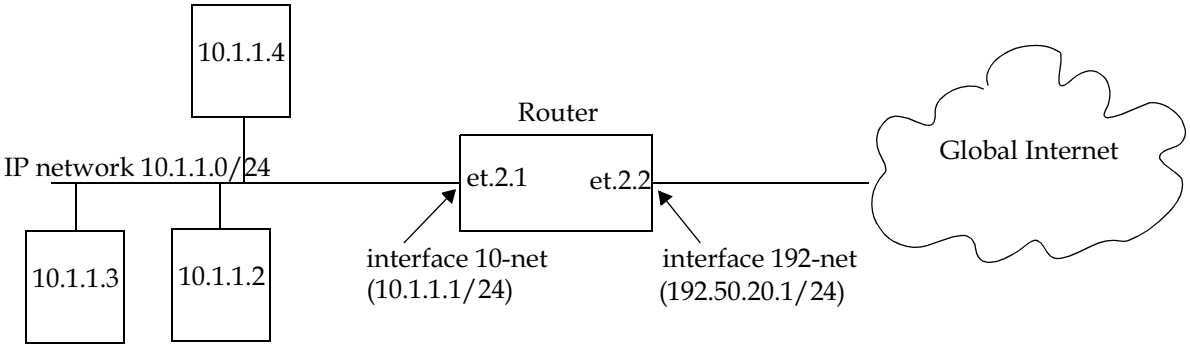

Figure 21-2 Dynamic address binding configuration

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.0/24
```


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Using Dynamic NAT

Dynamic NAT can be used when the local network (inside network) is going to initialize the connections. It creates a binding at run time when a packet is sent from a local network, as defined by the NAT dynamic local ACl pool. The network administrator does not have to worry about the way in which the bindings are created; the network administrator just sets the pools and the RS automatically chooses a free global IP from the global pool for the local IP.

Dynamic bindings are removed when the flow count for that binding goes to zero or the timeout has been reached. The free globals are used again for the next packet.

A typical problem is that if there are more local IP addresses as compared to global IP addresses in the pools, then packets will be dropped if all the globals are used. A solution to this problem is to use PAT with NAT dynamic. This is only possible with TCP or UDP protocols.

21.8.3 Dynamic NAT with IP Overload (PAT) Configuration

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside address 192.50.20.0/24:

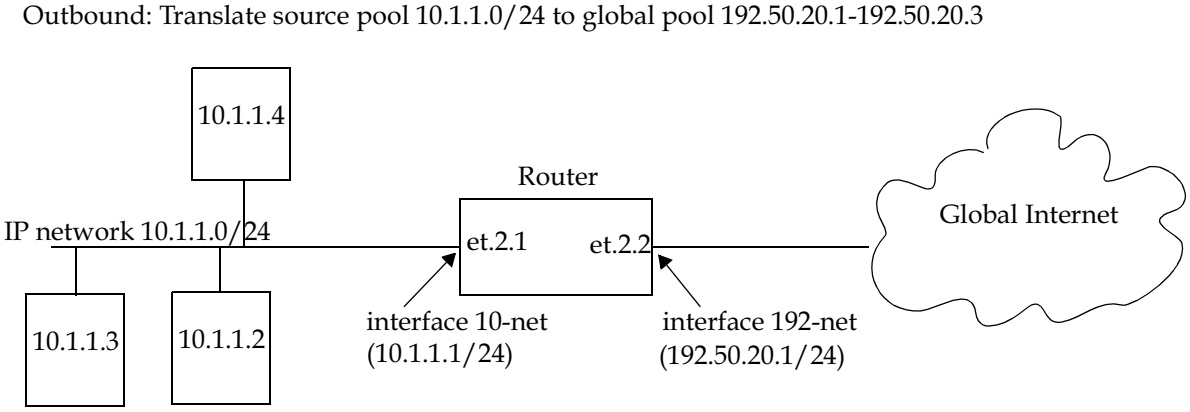

Figure 21-3 Dynamic address binding with PAT

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```


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3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.1-192.50.20.3
enable-ip-overload
```

Using Dynamic NAT with IP Overload

Dynamic NAT with IP overload can be used when the local network (inside network) will be initializing the connections using TCP or UDP protocols. It creates a binding at run time when the packet comes from a local network defined in the NAT dynamic local ACL pool. The difference between the dynamic NAT and dynamic NAT with PAT is that PAT uses port (layer 4) information to do the translation. Hence, each global IP has about 4000 ports that can be translated. NAT on the RS uses the standard BSD range of ports from 1024-4999 which is fixed and cannot be configured by the user. The network administrator does not have to worry about the way in which the bindings are created; he/she just sets the pools and the RS automatically chooses a free global IP from the global pool for the local IP.

Dynamic bindings are removed when the flow count goes to zero or the timeout has been reached. The removal of bindings frees the port for that global and the port is available for reuse. When all the ports for that global are used, then ports are assigned from the next free global. If no more ports and globals are available, the packets will be dropped.

21.8.4 Dynamic NAT with DNS

The following example configures a DNS dynamic address binding for outside address 192.50.20.2-192.50.20.9 to inside addresses 10.1.1.0/24:

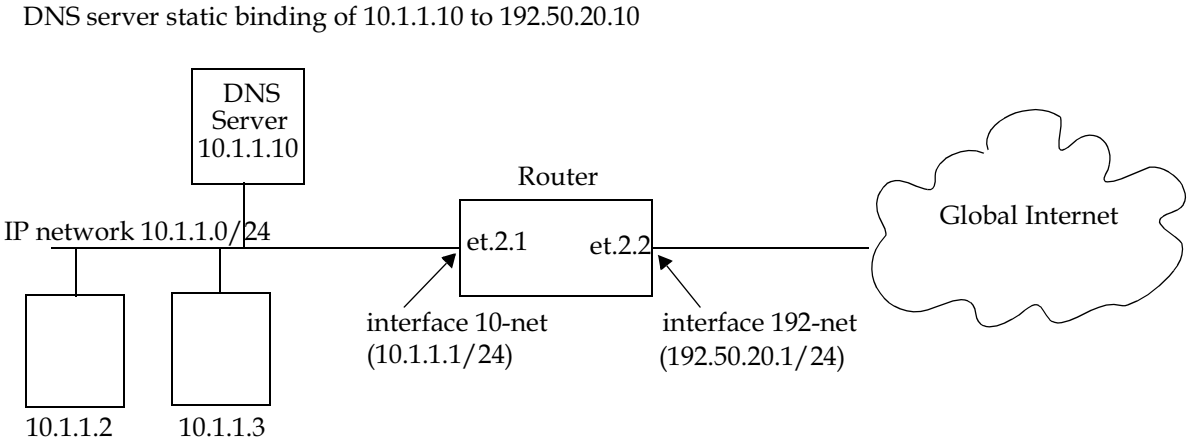

Figure 21-4 Dynamic address binding with DNS

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1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.2-192.50.20.9
nat create static local-ip 10.1.1.10 global-ip 192.50.20.10 protocol ip
```

Using Dynamic NAT with DNS

When a client from outside sends a query to the static global IP address of the DNS server, NAT will translate the global IP address to the local IP address of the DNS server. The DNS server will resolve the query and respond with a reply. The reply can include the local IP address of a host inside the local network (for example, 10.1.1.2); this local IP address will be translated by NAT into a global IP address (for example, 192.50.20.2) in a dynamic binding for the response.

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21.8.5 Dynamic NAT with Outside Interface Redundancy

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside addresses 192.50.20.0/24 on interface 192-net and to outside addresses 201.50.20.0/24 on interface 201-net:

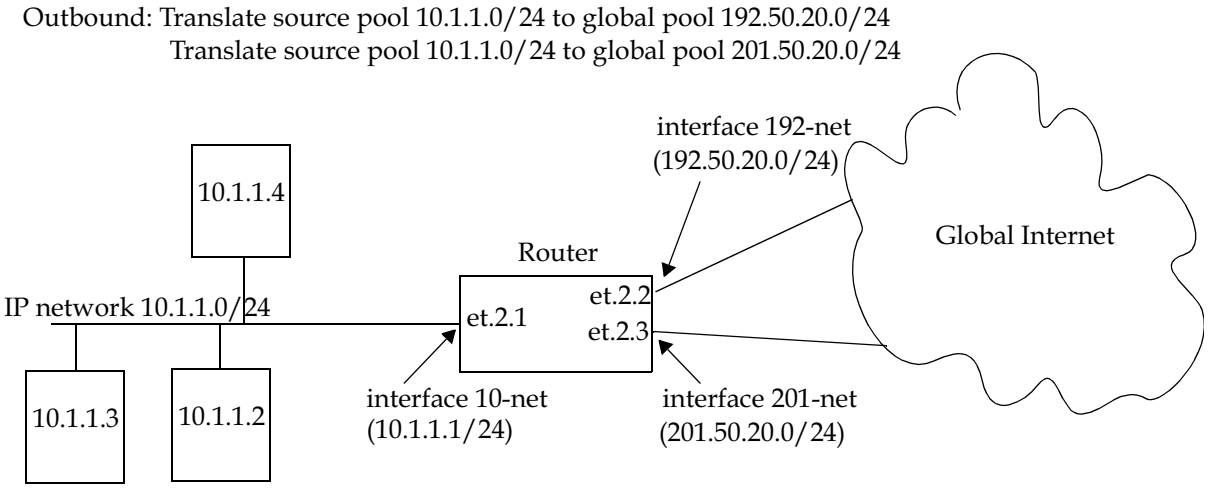

Figure 21-5 Dynamic address binding with outside interface redundancy

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.0/24 port et.2.2
interface create ip 201-net address-netmask 201.50.20.0/24 port et.2.3
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
nat set interface 201-net outside
```


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3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.0/24 matching-interface
192-net
nat create dynamic local-acl-pool lcl global-pool 210.50.20.0/24 matching-interface
201-net
```

Using Dynamic NAT with Matching Interface Redundancy

If you have redundant connections to the remote network via two different interfaces, you can use NAT for translating the local address to the different global pool specified for the two connections. This case is possible when you have two ISPs connected on two different interfaces to the Internet. Through a routing protocol, some routes will result in traffic going out of one interface and for others going out on the other interface. NAT will check which interface the packet is going out from before selecting a global pool. Hence, you can specify two different global pools with the same local ACL pool on two different interfaces.

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22 WEB HOSTING CONFIGURATION

Accessing information on websites for both work or personal purposes is becoming a normal practice for an increasing number of people. For many companies, fast and efficient web access is important for both external customers who need to access the company websites, as well as for users on the corporate intranet who need to access Internet websites.

The following features on the RS provide ways to improve web access for external and internal users:

- Load balancing allows incoming HTTP requests to a company's website to be distributed across several physical servers. If one server should fail, other servers can pick up the workload.
- Web caching allows HTTP requests from internal users to Internet sites to be redirected to cached Web objects on local servers. Not only is response time faster since requests can be handled locally, but overall WAN bandwidth usage is reduced.

Note Load balancing and web caching can be performed using application software. However, the RS can perform these functions much faster as the redirection is handled by specialized hardware.

22.1 LOAD BALANCING

You can use the load balancing feature on the RS to distribute session load across a group of servers. If you configure the RS to provide load balancing, client requests that go through the RS can be redirected to any one of several predefined hosts. With load balancing, clients access servers through a virtual IP address. The RS transparently redirects the requests with no change required on the clients or servers; all configuration and redirection is done on the RS.

Following are the steps in configuring load balancing on the RS:

1. Create a logical group of load balancing servers and define a virtual IP address for the group.
2. Define the servers in the group.
3. Specify optional operating parameters for the group of load balancing servers or for individual servers in the group.

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22.1.1 Creating the Server Group

To use load balancing, you create a logical group of load balancing servers and define a virtual IP address that the clients will use to access the server pool.

The following example configures the “abccompany-www” load balancing group:

```
rs(config)# load-balance create group-name abccompany-www virtual-ip
207.135.89.16 virtual-port 80 protocol tcp
```

Specifying a Protocol

When you configure a load balancing group, you need to specify the protocol of the traffic that will be load balanced. There is no default. Select the protocol based on what you think the majority of traffic will be for that group. For example, you may want to specify TCP if you expect the majority of traffic to be HTTP requests.

- Specify **ip** to perform Layer 3 load balancing. This protocol uses an IP-hash algorithm to load balance.
- Specify **tcp** if you want the RS to perform application load balancing and application health checks. You can specify a port to control which port performs the load balancing. If you don’t specify a port, any one of the ports in the group will be used for load balancing. When you specify **tcp** as the protocol, the default load balancing policy is round robin. You can change the load balancing policy to weighted round-robin, fastest, predictive, or least loaded. (See *"Specifying a Load Balancing Policy"* for more information about these policies.) UDP traffic through a TCP load-balanced group is load balanced using the IP hash algorithm.
- Specify **udp** to perform UDP load balancing, such as DNS. For UDP sessions, it is difficult to signal the end of a session because UDP is connectionless. Therefore, a fixed IP-hash policy is used to ensure that the client always goes to the same server.

Intrinsic Persistence Checking

Load balancing clients connect to a *virtual* IP address, which in reality is redirected to one of several physical servers in a load balancing group. In many web page display applications, a client may have its requests redirected to and serviced by different servers in the group. In certain situations, however, it may be critical that all traffic for the client be directed to the same physical server for the duration of the session; this is the concept of *session persistence*.

When the RS receives a new session request from a client for a specific virtual address, the RS creates a *binding* between the client (source) IP address/port socket and the (destination) IP address/port socket of the load balancing server selected for this client. Subsequent packets from clients are compared to the list of bindings: if there is a match, the packet is sent to the same server previously selected for this client; if there is not a match, a new binding is created. How the RS determines the binding match for session persistence is configured with the **persistence-level** option when the load balancing group is created.

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There are several configurable levels of session persistence:

- TCP persistence: a binding is determined by the matching the source IP/port address as well as the virtual destination IP/port address. For example, requests from the client address of 134.141.176.10:1024 to the virtual destination address 207.135.89.16:80 is considered one session and would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1). A request from a different source socket from the same client address to the same virtual destination address would be considered another session and may be directed to a different load balancing server (for example, the server with IP address 10.1.1.2). This is the default level of session persistence.
- SSL persistence: a binding is determined by matching the source IP address and the virtual destination IP/port address. Note that requests from *any* source socket with the client IP address are considered part of the same session. For example, requests from the client IP address of 134.141.176.10:1024 or 134.141.176.10:1025 to the virtual destination address 207.135.89.16:80 would be considered one session and would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1).
- Sticky persistence: a binding is determined by matching the source and destination IP addresses only. This allows all requests from a client to the same virtual address to be directed to the same load balancing server. For example, both HTTP and HTTPS requests from the client address 134.141.176.10 to the virtual destination address 207.135.89.16 would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1).
- Virtual private network (VPN) persistence: for VPN traffic using Encapsulated Security Payload (ESP) mode of IPSec, a binding is determined by matching the source and destination IP addresses in the secure key transfer request to subsequent client requests. This allows both the secure key transfer and subsequent data traffic from a particular client to be directed to the same load balancing server. The default port number recognized by the RS for secure key transfer in VPN is 500; you can use the **`load-balance set vpn-dest-port`** command to specify a different port number.
- IP persistence: Used for L3 persistence of load balancing sessions. Note that for IP persistence, there can be only one virtual IP address associated with one load balancing group. In addition, a load balancing server may belong to one IP group only.

The RS also supports *netmask persistence*, which can be used with any of the five levels of session persistence. A netmask (configured with the **`load-balance set client-proxy-subnet`** command) is applied to the source IP address and this address is compared to the list of bindings: if a binding exists, the packet is sent to the same load balancing server previously selected for this client; if there is not a match, a new binding is created.

This feature allows a range of source IP addresses (with different port numbers) to be sent to the same load balancing server. This is useful where client requests may go through a proxy that uses Network Address Translation or Port Address Translation or multiple proxy servers. During a session, the source IP address can change to one of several sequential addresses in the translation pool; the netmask allows client requests to be sent to the same server.

The following example configures the load balancing group “abccompany-www” with a persistence level of SSL:

```
rs(config)# load-balance create group-name abccompany-www virtual-ip
207.135.89.16 virtual-port 80 protocol tcp persistence-level ssl
```

22.1.2 Adding Servers to the Load Balancing Group

Once a logical server group is created, you specify the servers that can handle client requests. When the RS receives a client request directed to the virtual server address, it redirects the request to an actual server address and port. Server selection is done according to the specified policy.

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The following example adds servers to the “abccompany-www” load balancing group:

```
rs(config)# load-balance add host-to-group 10.1.1.1-10.1.1.4 group-name
abccompany-www port 80
```

You can add backup servers to a load balancing group by specifying the **status backup** parameter in the **load-balance add host-to-group** command. The backup servers are sent client requests *only* if a load balancing server or an application on a load balancing server is “down” (as determined by the RS’s verification checking). In the following example, the server with an IP address of 10.1.1.5 is added as a backup server:

```
rs(config)# load-balance add host-to-group 10.1.1.5 group-name
abccompany-www port 80 status backup
```

You can also issue the **load-balance set server-status** command to set a load balancing server to a “down” state. When the server or application that was “down” is again able to receive requests, the backup server finishes processing its current client requests but no new requests will be directed to it.

22.1.3 Setting Timeouts for Load Balancing Mappings

The mapping between a host (source) and a load-balancing server (destination) times out after a certain period of non-activity. After the mapping times out, any server in the load balancing group can be selected. The default timeout depends upon the session persistence level configured, as shown below:

Table 22-1 Default binding timeouts

Persistence Level	Default Binding Timeout
TCP	3 minutes
SSL	120 minutes
Sticky	120 minutes
VPN	3 minutes
IP	3 minutes

You can change the default timeout for a server group with the **load-balance set aging-for-src-maps** command. In the following example, the default timeout was changed to 100 for the “mktgroup” server group. All other groups use the defaults listed in Table 22-1:

```
rs(config)# load-balance set aging-for-src-maps mktgroup aging-time 100
```

You can use the **load-balance show source-mappings** command to display information about the current list of bindings.

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22.1.4 Optional Group or Server Operating Parameters

The **load-balance set server-options** command and **load-balance set group-options** command have several parameters that affect the operations of individual servers or the entire group of load balancing servers. In many cases, there are default parameter values and you only need to specify a different value if you wish to change the default operation. For example, you can specify the policy to be used for distributing the workload for a group of load balancing servers created with the parameter **protocol tcp**. By default, the RS assigns sessions to these servers in a round-robin (sequential) manner.

Specifying a Load Balancing Policy

The default policy for distributing workload among load balancing servers is "round-robin," where the RS selects the server on a rotating basis without regard to the load on individual servers. Other policies can be chosen for the group as follows:

- least loaded, where the server with the fewest number of sessions bound to it is selected to service a new session.
- weighted round robin, a variation of the round-robin policy where each server takes on new sessions according to its assigned weight. If you choose the weighted round robin policy, you must assign a weight to each server that you add to the load balancing group.
- fastest, where the server with the fastest response time is selected to service a new session.
- predictive, where the server with the fastest decreasing response time is selected to service a new session.

Note These policies only affect TCP traffic; UDP and IP traffic are load-balanced using a fixed IP-hash policy.

The following example sets the load balancing policy of the "mktgroup" server group to least-loaded:

```
rs(config)# load-balance set group-options mktgroup policy least-loaded
```

Specifying a Connection Threshold

By default, there is no limit on the number of sessions that a load balancing server can service. You can specify the maximum number of connections that each server in a group can service. The following example sets the maximum number of connections for each server in the "mktgroup" group:

```
rs(config)# load-balance set group-options mktgroup group-conn-threshold 800
```

Note This limits the number of connections for *each* server in the group, not the total number of connections for the group.

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Checking Servers and Applications

The RS *automatically* performs the following types of verification for the attached load balancing servers/applications:

- Verifies the state of the server by sending a ping to the server at 5-second intervals. If the RS does not receive a reply from a server after four ping requests, the server is considered to be "down."
- Checks that an application session on the server can be established by doing a simple TCP handshake with the application on the configured physical port of the server at 15-second intervals. If the RS does not receive a reply from the application after four tries, the application is considered to be "down."

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the server or application to be "down." You can change these parameters for all servers in a load balancing group or for specific servers.

The following example modifies the defaults for the pings from the RS to the "mktgroup" server group:

```
rs(config)# load-balance set group-options mktgroup ping-tries 3 ping-int 10
```

The following example sets the time between handshakes at port 80:

```
rs(config)# load-balance set server-options 135.142.179.14 app-int 8 port 80
```

In addition, the RS can also check the status of any attached Domain Name Servers (DNS) servers and RADIUS servers. To verify the state of a DNS server, the RS sends a lookup request for a host name. The RS then checks the response of the DNS server for the specified IP address and host-name. The following example sets the IP address and host name:

```
rs(config)# load-balance set group-options mktgroup dns-host-ip 135.142.179.10
dns-host-name www-fast
```

The RS verifies the status of a RADIUS server by sending it queries and verifying the response it receives. You define the user name, password, and MD5 encryption key that the RS will include in its queries. You can specify invalid values for the user name and password. A positive response to a query with valid values or a negative response to a query with invalid values indicates that the RADIUS server is "up." The following example sets the values for the query to the RADIUS server:

```
rs(config)# load-balance set group-options mktgroup radius-username radiusserv
radius-password a1b2c3e4f5 radius-md5 abcdegh
```


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Verifying Extended Content (Comprehensive Server Checking)

You can also have the RS verify the *content* of an application on one or more load balancing servers. For this type of verification, specify the following:

- A string that the RS sends to a single server or to the group of load balancing servers. The string can be a simple HTTP command to get a specific HTML page. Or, it can be a command to execute a user-defined CGI script that tests the operation of the application.
- The reply that the application on each server sends back. The RS uses this reply to validate the content. In the case where a specific HTML page is retrieved, the reply can be a string that appears on the page, such as "OK." If a CGI script is executed on the server, it should return a specific response (for example, "OK") that the RS can verify.

Note that you can specify this type of verification for a group of load balancing servers or for a specific server.

Application verification, whether a simple TCP handshake or a user-defined action-response check, involves opening and closing a connection to a load balancing server. Some applications require specific commands for proper closure of the connection. For example, a connection to an SMTP server application should be closed with the "quit" command. You can configure the RS to send a specific string to close a connection on a server.

If you have a proprietary protocol, you can verify whether the protocol is "up" by specifying the files for the application content verification request, reply and quit strings.

22.1.5 Using Health Check Clusters

The RS automatically performs health checks on its attached load balancing servers. It verifies the state of each server and checks that an application session on the server can be established. When a load balancing server has multiple IP addresses, you can configure a health check cluster so the RS health checks only one designated IP address instead of all the IP addresses assigned to the server.

Following are the steps for configuring a health check cluster:

1. Create the health check cluster.
2. Add servers to the health check cluster.
3. Optionally, set parameters for the health check cluster.

The following example configures the "hcc1" health check cluster:

```
load-balance create health-check-cluster hcc1 ip-to-check 135.142.179.12 port-to-check
10
load-balance add-host-to-group 135.142.179.15-135.142.179.18 group-name hcc1
health-check-cluster hcc1
```

22.1.6 Setting Server Status

It may become necessary at times to prevent new sessions from being directed to one or more load balancing servers. For example, if you need to perform maintenance tasks on a server system, you might want new sessions to temporarily *not* be directed to that server. Setting the status of a server to "down" prevents new sessions from being directed to that server. The "down" status does not affect any current sessions on the server. When the server is again ready to accept new sessions, you can set the server status to "up."

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The following example sets the status of port 80 at address 135.142.179.14 to up:

```
rs # load-balance set server-status server-ip 135.142.179.14
server-port 80 group-name engservers status up
```

22.1.7 Load Balancing and FTP

File Transfer Protocol (FTP) packets require special handling with load balancing, because the FTP packets contain IP address information within the data portion of the packet. If the FTP control port used is not port 21, it is important for the RS to know the port number that is used for FTP. Therefore you need to specify the FTP control port as shown in the following example:

```
rs(config)# load-balance set ftp-control-port 10
```

22.1.8 Allowing Load Balancing Servers to Access the Internet

A load balancing server may need to occasionally make its own request to the Internet in order to complete a client's request. For example, a DNS server that is being load balanced may need to send a request to another DNS server on the Internet to resolve a hostname. To allow Network Address Translation (NAT) for the server's Internet request (and the reply), you must specify the port numbers that the load balancing servers will use for these requests.

Following example specifies a range of ports for Internet requests by the "mktgroup" load balancing group:

```
rs(config)# load-balance set wildcard-lsnapt-range mktgroup
source-port-range 11-15
```

22.1.9 Allowing Access to Load Balancing Servers

Load balancing causes both source and destination addresses to be translated on the RS. It may be undesirable in some cases for a source address to be translated; for example, when data is to be updated on an individual server. Specified hosts can be allowed to directly access servers in the load balancing group without address translation. Note, however, that such hosts cannot use the virtual IP address and port number to access the load balancing group of servers.

In the following example, access is allowed to servers in the IP address range of 135.142.179.14 to 135.142.179.21:

```
rs(config)# load-balance allow access-to-servers client-ip
135.142.179.14-135.142.179.21 group-name mktgroup
```

22.1.10 Virtual State Replication Protocol (VSRP)

VSRP provides redundancy in a dual load balancer setting. It runs between two RS's that have the same load balancing group configured, enabling them to mirror each other's session information for a particular load balancing group. VSRP runs in the active-active mode, so the RS's share persistence information in real time. Thus, should one RS go down, the other is able to immediately take over.

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For VSRP to run properly, configure the same load balancing group on the two RS's. (Note that the group's configuration on both RS's should be exactly the same.) Then, enter the **`load-balance create state-mirror-peer`** command and the **`load-balance add group-for-mirroring`** command on both RS's.

VSRP Example

The group www.fast.net is configured on two RS's. The IP address of RS A is 100.1.1.1 and the IP address of RS B is 100.1.1.2. The two RS's are configured to mirror each other's session information for the group www.fast.net.

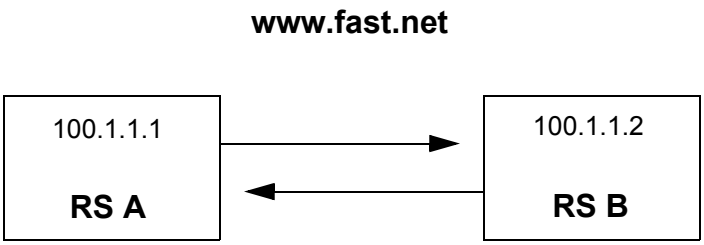

Figure 22-1 VSRP configuration example

To mirror the sessions of RS A, enter the following commands on RS A:

```
load-balance create state-mirror-peer 100.1.1.2 src-ip-to-use 100.1.1.1
load-balance add group-for-mirroring www.fast.net ip-of-peer 100.1.1.2
```

To mirror the sessions of RS B, enter the following commands on RS B:

```
load-balance create state-mirror-peer 100.1.1.1 src-ip-to-use 100.1.1.2
load-balance add group-for-mirroring www.fast.net ip-of-peer 100.1.1.1
```


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22.1.11 Displaying Load Balancing Information

To display load balancing information, enter the following commands in Enable mode:

Show the groups of load balancing servers.	**load-balance show virtual-hosts [group-name** *<group name>***][virtual-ip** *<ipaddr>***][virtual-port** *<port number>*|*ip***]**
Show source-destination bindings.	**load-balance show source-mappings [client-ip** *<ipaddr/range>***][virtual-ip** *<ipaddr>***][virtual-port** *<port number>*|*ip***] [destination-host-ip** *<ipaddr>***]**
Show load balancing statistics.	**load-balance show statistics [group-name** *<group name>***][virtual-ip** *<ipaddr>***] [virtual-port** *<port number>*|*ip***]**
Show load balance hash table statistics.	**load-balance show hash-stats**
Show load balance options for verifying the application.	**load-balance show acv-options [group-name** *<group name>***][destination-host-ip** *<virtual-ipaddr>***][destination-host-port** *<virtual-port-number>*|*ip***]**
Show information about the health check clusters.	**load-balance show health-check-clusters**
Show session mirroring information.	**load-balance show session-mirror-info peer-ip** *<ipaddr>*

22.1.12 Configuration Examples

This section shows examples of load balancing configurations.

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Web Hosting with One Virtual Group and Multiple Destination Servers

In the following example, a company web site is established with a URL of www.abccompany.com. The system administrator configures the networks so that the RS forwards web requests among four separate servers, as shown below.

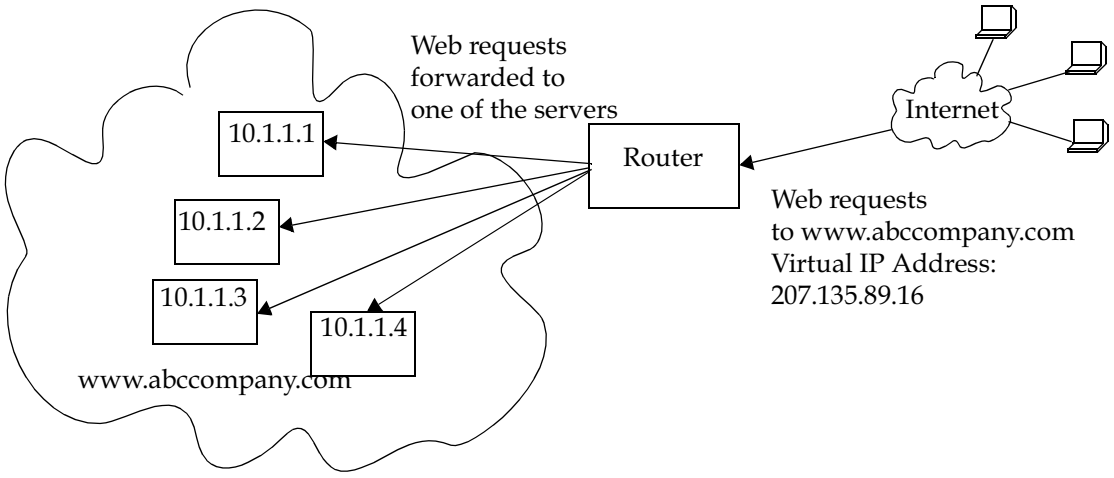

Figure 22-2 Load balancing with one virtual group

Domain Name	Virtual IP	TCP Port	Real Server IP	TCP Port
www.abccompany.com	207.135.89.16	80	10.1.1.1	80
			10.1.1.2	80
			10.1.1.3	80
			10.1.1.4	80

The network shown above can be created with the following **load-balance** commands:

```
load-balance create group-name abccompany-www virtual-ip 207.135.89.16 virtual-port 80
protocol tcp
load-balance add host-to-group 10.1.1.1-10.1.1.4 group-name abccompany-www port 80
```


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The following is an example of how to configure a simple verification check where the RS will issue an HTTP command to retrieve an HTML page and check for the string “OK”:

```
load-balance set group-options abccompany-www acv-command “GET /test.html” acv-reply
“OK” read-till-index 25
```

The **read-till-index** option is not necessary if the file test.html contains “OK” as the first two characters. The **read-till-index** option is helpful if the exact index of the **acv-reply** string in the file is not known to the user. In the above example, the RS will search from the beginning of the file up to the 25th character for the start of the string “OK.”

Web Hosting with Multiple Virtual Groups and Multiple Destination Servers

In the following example, three different servers are used to provide different services for a site.

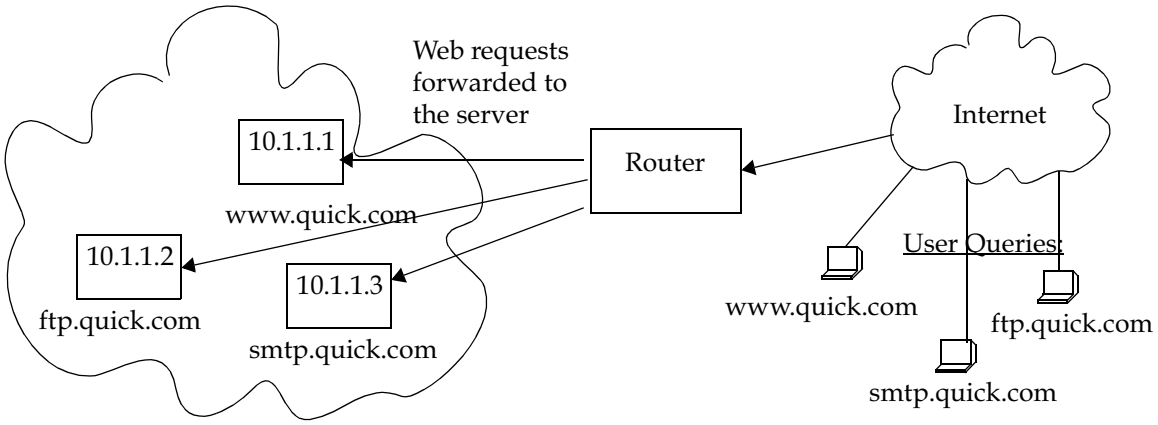

Figure 22-3 Load balancing with multiple virtual groups

Domain Name	Virtual IP	TCP Port	Real Server IP	TCP Port
www.quick.com	207.135.89.16	80	10.1.1.1	80
ftp.quick.com	207.135.89.16	21	10.1.1.2	21
smtp.quick.com	207.135.89.16	25	10.1.1.3	25

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The network shown above can be created with the following load-balance commands:

```
load-balance create group-name quick-www virtual-ip 207.135.89.16 virtual-port 80
protocol tcp
load-balance create group-name quick-ftp virtual-ip 207.135.89.16 virtual-port 21
protocol tcp
load-balance create group-name quick-smtp virtual-ip 207.135.89.16 virtual-port 25
protocol tcp
load-balance add host-to-group 10.1.1.1 group-name quick-www port 80
load-balance add host-to-group 10.1.1.2 group-name quick-ftp port 21
load-balance add host-to-group 10.1.1.3 group-name quick-smtp port 25
```

If no application verification options are specified, the RS will do a simple TCP handshake to check that the application is "up." Some applications require specific commands for proper closure of the connection. The following command shows an example of how to send a specific string to close a connection on a server:

```
load-balance set group-options quick-smtp acv-quit "quit"
```

Virtual IP Address Ranges

ISPs who provide web hosting services for their clients require a large number of virtual IP addresses (VIPs). The **load-balance create vip-range-name** and **load-balance add host-to-vip-range** commands were created specifically for this. An ISP can create a range of VIPs for up to an entire class C network with the **load-balance create vip-range-name** command. Once the vip-range is in place, the ISP can then create the corresponding secondary addresses on their destination servers. Once these addresses have been created, the ISP can add these servers to the vip-range with the **load-balance add host-to-vip-range** command. These two commands combined help ISPs take advantage of web servers like Apache that serve different web pages based on the destination address in the HTTP request.

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The following example illustrates this.

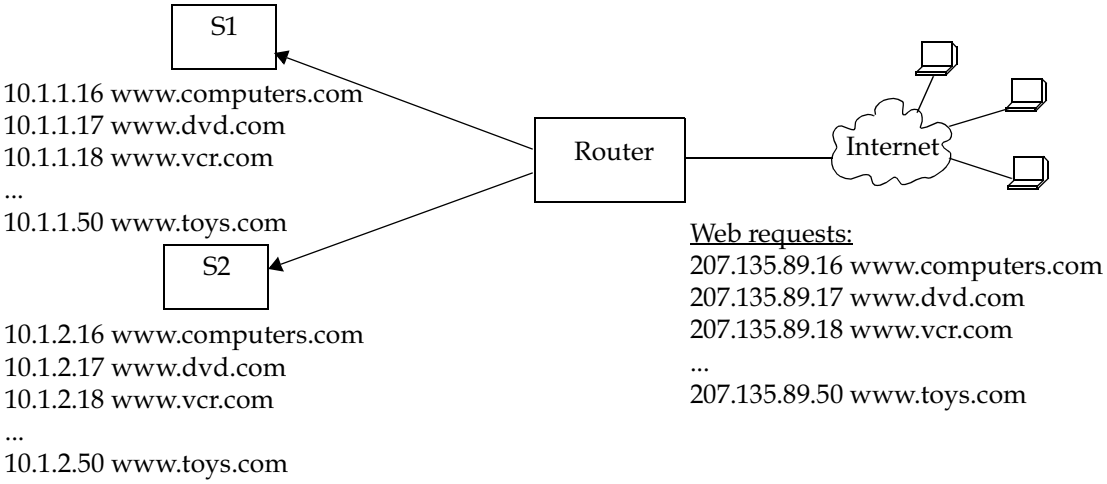

Figure 22-4 Virtual IP address ranges

Group Name	Virtual IP	TCP Port	Destination Server IP	TCP Port
www.computers.com	207.135.89.16	80	S1: 10.1.1.16 S2: 10.1.2.16	80
www.dvd.com	207.135.89.17	80	S1: 10.1.1.17 S2: 10.1.2.17	80
www.vcr.com	207.135.89.18	80	S1: 10.1.1.18 S2: 10.1.2.18	80
www.toys.com	207.135.89.50	80	S1: 10.1.1.50 S2: 10.1.2.50	80

The network shown in the previous example can be created with the following load-balance commands:

```
load-balance create vip-range-name mywwwrange 207.135.89.16-207.135.89.50
virtual-port 80 protocol tcp
load-balance add host-to-vip-range 10.1.1.16-10.1.1.50 vip-range-name mywwwrange port
80
load-balance add host-to-vip-range 10.1.2.16-10.1.2.50 vip-range-name mywwwrange port
80
```


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Session and Netmask Persistence

In the following example, traffic to a company web site (www.abccompany.com) is distributed between two separate servers. In addition, client traffic will have two separate ranges of source IP addresses. The same load balancing server will handle requests from clients of the same source IP subnet address.

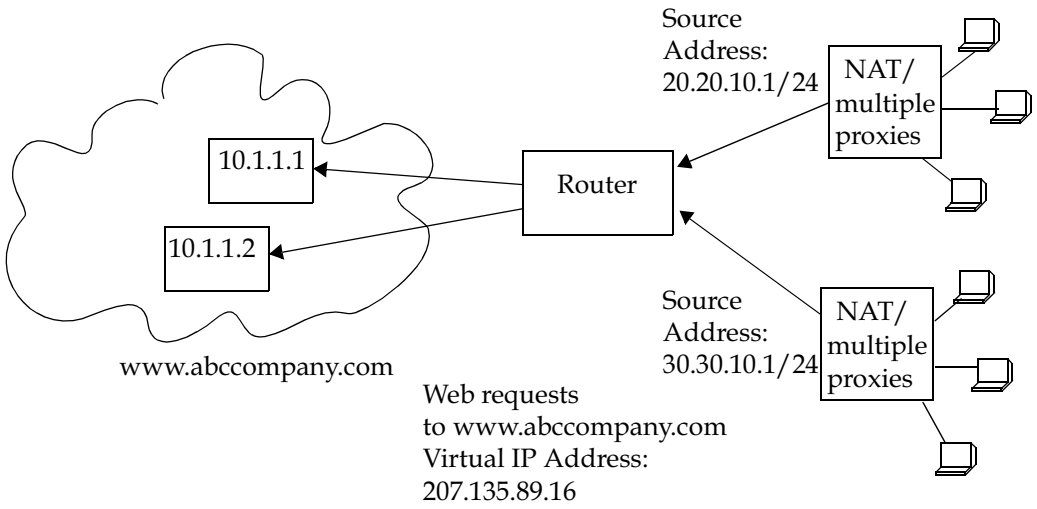

Figure 22-5 Session and netmask persistence

Client IP Address	Domain Name	Virtual IP	Real Server IP	TCP Port
20.20.10.1 - 20.20.10.254	www.abccompany.com	207.135.89.16	10.1.1.1	80
30.30.10.1 - 30.30.10.254			10.1.1.2	80

The network shown above can be created with the following load-balance commands:

```
load-balance create group-name abccompany-sec virtual-ip 207.135.89.16 protocol tcp
persistence-level ssl virtual-port 443
load-balance add host-to-group 10.1.1.1-10.1.1.2 group-name abccompany-sec port 443
load-balance set client-proxy-subnet abccompany-sec subnet 24
```


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Load Balancing with NAT

In the following example, several services (including DNS) are distributed between two separate servers. Occasionally, the load balancing server will need to make its own DNS request to the Internet in order to resolve a client's DNS request. Network Address Translation (NAT) on the RS allows the load balancing servers to use a "global" IP address for Internet requests. NAT translates the "local" address of the load balancing server to the global address for the outgoing request and translates the global address back to the local address for the incoming reply. This process is illustrated in Figure 22-6.

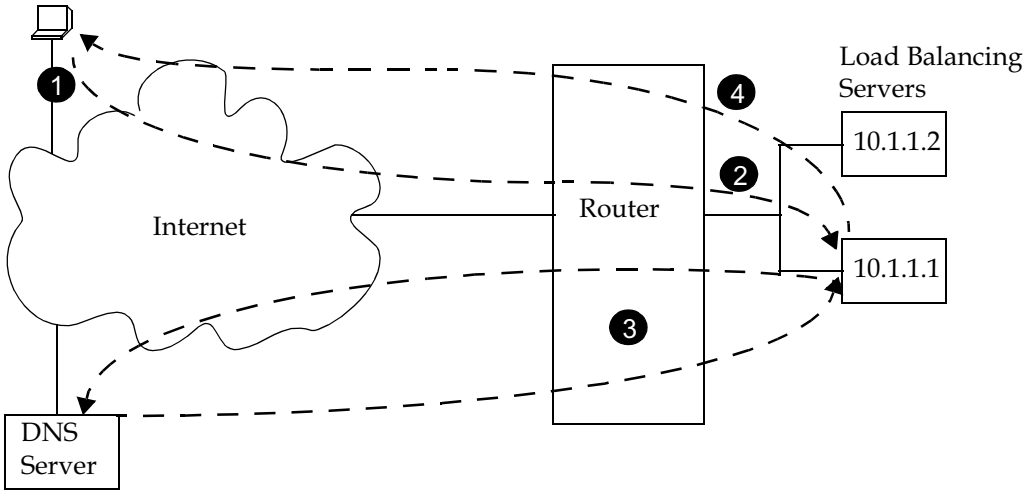

Figure 22-6 Load balancing with NAT

The following explains the data flows shown in Figure 22-6:

1. The client sends a DNS request to the virtual IP address 135.1.1.1:53.
2. The client's DNS request is redirected to a load balancing server.
3. The load balancing server sends a request to an authoritative DNS server on the Internet. NAT on the RS translates the load balancing server's internal IP address (10.1.1.1) to the global IP address 136.1.1.100 for the request. For the reply, NAT translates the global IP address back to the internal IP address and sends the reply message to the load balancing server.
4. The load balancing server sends a DNS reply back to the client.

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The network shown in the example can be created with the following commands:

```
! create the load balancing group 'service2' with virtual IP address 135.1.1.1
load-balance create group-name service2 virtual-ip 135.1.1.1 protocol udp
load-balance add host-to-group 10.1.1.1-10.1.1.2 group-name service2
load-balance set wildcard-lsnapt-range service2 source-port-range 1024-65535

! traffic from these source ports will not be translated by NAT
acl nat-acl deny tcp any any 53 any
acl nat-acl deny udp any any 53 any
acl nat-acl deny tcp any any 80 any
acl nat-acl deny tcp any any 443 any

! traffic from these source ports will be translated by NAT
acl nat-acl permit tcp 10.1.0.0/16 any 1024-65535 any
acl nat-acl permit udp 10.1.0.0/16 any 1024-65535 any

! requests from 10net servers using ports 1024-65535 are translated to global
! address 136.1.1.100 with PAT, and vice versa
nat set interface 10net inside
nat set interface 136net outside
nat create dynamic local-acl-pool nat-acl global-pool 136.1.1.100 enable-ip-overload
```

22.2 WEB CACHING

Web caching provides a way to store frequently accessed Web objects on a cache of local servers. Each HTTP request is transparently redirected by the RS to a configured cache server. When a user first accesses a Web object, that object is stored on a cache server. Each subsequent request for the object uses this cached object. Web caching allows multiple users to access Web objects stored on local servers with a much faster response time than accessing the same objects over a WAN connection. This can also result in substantial cost savings by reducing the WAN bandwidth usage.

Note The RS itself does not act as cache for web objects. It redirects HTTP requests to local servers on which the web objects are cached. One or more local servers are needed to work as cache servers with the RS's web caching function.

22.2.1 Configuring Web Caching

The following are the steps in configuring Web caching on the RS:

1. Create the cache group (a list of cache servers) to cache Web objects.
2. Specify the hosts whose HTTP requests will be redirected to the cache servers. This step is optional; if you do not explicitly define these hosts, then *all* HTTP requests are redirected.
3. Apply the caching policy to an outbound interface or port to redirect HTTP traffic on that interface or port to the cache servers.

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Creating the Cache Group

You can specify either a range of contiguous IP addresses or a list of up to four IP addresses to define the servers when the cache group is created. If you specify multiple servers, load balancing is based on the destination address of the request. If any cache server fails, traffic is redirected to the other active servers.

The following example configures the "testweb1" caching policy for the "weblist1" cache group:

```
rs(config)# web-cache testweb1 create server-list weblist1 range
"10.10.10.1 10.10.10.100"
```

Note If a range of IP addresses is specified, the range must be contiguous and contain no more than 256 IP addresses.

Specifying the Client(s) for the Cache Group (Optional)

You can explicitly specify the hosts whose HTTP requests are or are not redirected to the cache servers. If you do not explicitly specify these hosts, then *all* HTTP requests are redirected to the cache servers.

The following example specifies that HTTP requests from the address range 135.142.179.14 to 135.142.179.21 should be redirected to the cache servers:

```
rs(config)# web-cache testweb1 permit hosts range "135.142.179.14
135.142.179.21"
```

Redirecting HTTP Traffic on an Interface or Port

To start the redirection of HTTP requests to the cache servers, you need to apply the caching policy to a specific outbound interface or port. This interface or port is typically an interface that connects to the Internet. If you apply the caching policy to an interface, the interface should not be on the same subnet as the web cache servers.

Apply a caching policy to a port when redirecting bridged traffic. You should apply it to the port that leads to the web server. L4 bridging must be enabled, and the clients, servers, and ports must belong to the same VLAN. In addition, for 802.1Q trunk ports, you can specify a particular VLAN.

Note By default, the RS redirects HTTP requests on port 80. Secure HTTP (https) requests do not run on port 80, therefore these types of requests are not redirected by the RS.

The following example applies the policy "testweb1" to port et.3.1:

```
rs(config)# web-cache testweb1 apply port et.3.1
```


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22.2.2 Configuration Example

In the following example, a cache group of seven local servers is configured to store Web objects for users in the local network:

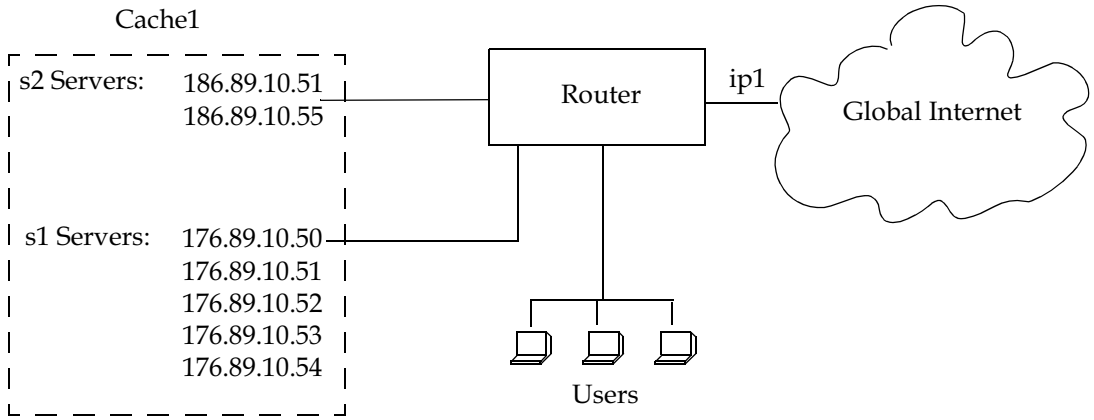

Figure 22-7 Web cache configuration

The following commands configure the cache group ‘cache1’ that contains the servers shown in the figure above and applies the caching policy to the interface ‘ip1’:

```
rs(config)# web-cache cache1 create server-list s1 range “176.89.10.50 176.89.10.54”
rs(config)# web-cache cache1 create server-list s2 list “186.89.10.51 186.89.10.55”
rs(config)# web-cache cache1 apply interface ip1
```

Note that in this example, HTTP requests from *all* hosts in the network are redirected as there are no **`web-cache permit`** or **`web-cache deny`** commands.

22.2.3 Other Web-Cache Options

This section discusses other commands that may be useful in configuring Web caching in your network.

Bypassing Cache Servers

Some Web sites require source IP address authentication for user access, therefore HTTP requests for these sites *cannot* be redirected to the cache servers. You can specify the sites for which HTTP requests are not redirected to the cache servers, as shown in the following example:

```
rs(config)# web-cache testweb1 create bypass-list range “135.142.179.14
135.142.179.21”
```


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In the preceding example, a bypass list for testweb1 is created. The list has an address range of 135.142.179.14 to 135.142.179.21. HTTP requests for these sites will not be redirected

Proxy Server Redundancy

Some networks use proxy servers that receive HTTP requests on a non-standard port number (i.e., not port 80). When the proxy server is available, all HTTP requests are handled by the proxy server. The RS can provide proxy server redundancy by transparently redirecting HTTP connections to the cache servers should the proxy server fail. To achieve this, the RS must be configured to redirect HTTP requests on the (non-standard) HTTP port used by the proxy server.

In the following example, the HTTP port number for testweb1 is set to port 40:

```
rs(config)# web-cache testweb1 set http-port 40
```

Disabling Redirection on an Inbound Interface or Port

When you apply a caching policy, HTTP requests that are received on *all* inbound interfaces on the RS are redirected to the local cache servers. You can specify that redirection of requests *not* be done for a particular inbound interface or port.

In the following example, HTTP requests on the interface int100 will not be redirected:

```
rs(config)# web-cache testweb1 create filter interface int100
```

Specifying Protocol for Redirected Traffic

By default, only TCP traffic is redirected to the local cache servers. You can specify a different IP protocol for the traffic that is to be redirected. For example, you can specify that UDP traffic be redirected. For any protocol other than TCP or UDP, you will need to specify the assigned IP protocol number as defined in RFC 1060.

The following example specifies that UDP traffic will be redirected:

```
rs(config)# web-cache testweb1 set redirect protocol udp
```

Configuring the traffic to be redirected (with the **`web-cache set redirect-protocol`** command) and the HTTP port (with the **`web-cache set http-port`** command) allows transparent redirection of traffic for any application that is supported by the cache servers.

Distributing Frequently-Accessed Sites Across Cache Servers

The RS uses the destination IP address of the HTTP request to determine to which cache server to send the request. However, if there is a Web site that is being accessed very frequently, the cache server serving requests for this destination address may become overloaded with user requests. You can specify one of the following policies for distributing certain destination addresses across the cache servers:

- round-robin, where the RS selects the cache server on a rotating basis regardless of the load on individual servers

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- weighted round robin, a variation of the round-robin policy where the RS selects the cache server according to its assigned weight
- weighted hash.

When you select either weighted round robin or weighted hash, you will need to specify the weight of the server group with the **web-cache set server-options** command.

The following example specifies that the weighted round-robin policy will be used to distribute the specified address range across the cache servers:

```
rs(config)# web-cache testweb1 selection-policy weighted-round-robin range
“135.142.179.14 135.142.179.21”
rs(config)# web-cache testweb1 set server-options webgrp1 wrr-weight 2
```

Specifying a Connection Threshold

By default, the RS will redirect up to 2000 HTTP requests to a web caching server. You can configure the maximum number of connections that each server can handle.

The following example sets the maximum number of connections to 200:

```
rs(config)# web-cache testweb1 set maximum-connections webgrp1 200
```

Note This command limits the number of connections for *each* server in the group, not the total number of connections for the group.

Verifying Servers

The RS can verify the state of the cache server by sending a ping to the server at 5-second intervals. If the RS does not receive a reply from a server after four ping requests, the server is considered to be “down.”

If you specify that the RS use TCP connection requests to check the gateway (instead of sending ICMP echo requests), the RS checks that an application session on the server can be established by sending a TCP connection request to the application on the configured port of the server at 15-second intervals. If the RS does not receive a reply from the application after four tries, the application is considered to be “down.”

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the server or application to be “down.”

In the following example, the servers in the weblist1 server group will be pinged at 7-second intervals. If the RS does not receive a reply after 3 ping requests, the server will be considered “down.”

```
rs(config)# web-cache testweb1 set server-options weblist1 ping-tries 3
ping-int 7
```


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22.2.4 Monitoring Web-Caching

To display Web-caching information, enter the following commands in Enable mode.

Show information for all caching policies and all server lists.	**web-cache show all**
Show caching policy information.	**web-cache show cache-name** <*cache-name*> **|all**
Show cache server information.	**web-cache show servers cache** <*cache-name*> **|all**
Show statistics for the specified cache policy.	**web-cache show statistics**

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23 IPX ROUTING CONFIGURATION

The Internetwork Packet Exchange (IPX) is a datagram connectionless protocol for the Novell NetWare environment. You can configure the RS for IPX routing and SAP. Routers interconnect different network segments and by definitions are network layer devices. Thus routers receive their instructions for forwarding a packet from one segment to another from a network layer protocol. IPX, with the help of RIP and SAP, perform these Network Layer Task. These tasks include addressing, routing, and switching information packets from one location to another on the internetwork.

IPX defines internetwork and intranode addressing schemes. IPX internetwork addressing is based on network numbers assigned to each network segment on a Novell NetWare internetwork. The IPX intranode address comes in the form of socket numbers. Because several processes are normally operating within a node, socket numbers provide a way for each process to distinguish itself.

The IPX packet consists of two parts: a 30-byte header and a data portion. The network node and socket addresses for both the destination and source are held within the IPX header.

23.1 RIP (ROUTING INFORMATION PROTOCOL)

IPX routers use RIP to create and dynamically maintain a database of internetwork routing information. RIP allows a router to exchange routing information with a neighboring router. As a router becomes aware of any change in the internetwork layout, this information is immediately broadcast to any neighboring routers. Routers also send periodic RIP broadcast packets containing all routing information known to the router.

The RS uses IPX RIP to create and maintain a database of internetwork routing information. The RS' implementation of RIP allows the following exchanges of information:

- Workstations locate the fastest route to a network number by broadcasting a route request.
- Routers request routing information from other routers to update their own internal tables by broadcasting a route request.
- Routers respond to route requests from workstations and other routers.
- Routers perform periodic broadcasts to make sure that all other routers are aware of the internetwork configuration.
- Routers perform broadcasting whenever they detect a change in the internetwork configurations.

The RIP implementation on the RS follows the guidelines in Novell's *IPX RIP and SAP Router Specification Version 1.30* document.

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23.2 SAP (SERVICE ADVERTISING PROTOCOL)

SAP provides routers with a means of exchanging internetwork service information. Through SAP, servers advertise their services and addresses. Routers gather this information and share it with other routers. This allows routers to create and dynamically maintain a database of internetwork service information. SAP allows a router to exchange information with a neighboring SAP agent. As a router becomes aware of any change in the internetwork server layout, this information is immediately broadcast to any neighboring SAP agents. SAP broadcast packets containing all server information known to the router are also sent periodically.

The RS uses IPX SAP to create and maintain a database of internetwork service information. The RS's implementation of SAP allows the following exchanges of information:

- Workstations locate the name and address of the nearest server of certain type
- Routers request the names and addresses of either all or certain type of servers
- Servers respond to the workstation's or router's request
- Routers make periodic broadcasts to make sure all other routers are aware of the internetwork configuration
- Routers perform broadcasting whenever they detect a change in the internetwork configurations

23.3 CONFIGURING IPX RIP & SAP

This section provides an overview of configuring various IPX parameters and setting up IPX interfaces.

23.3.1 IPX RIP

On the RS, RIP automatically runs on all IPX interfaces. The RS will keep multiple routes to the same network having the lowest ticks and hop count. Static routes can be configured on the RS using the CLI's **`ipx add route`** command. Through the use of RIP filters, the RS can control the acceptance and advertisement of networks per-interface.

23.3.2 IPX SAP

On the RS, SAP automatically runs on all the IPX interfaces. The RS will keep multiple SAPs having the lowest hop count. Static SAPs can be configured on the RS using the CLI's **`ipx add sap`** command. Through the use of SAP filters, the RS can control the acceptance and advertisements of services per-interface.

23.3.3 Creating IPX Interfaces

When you create IPX interfaces on the RS, you provide information about the interface (such as its name, output MAC encapsulation, and IPX address). You also enable or disable the interface and bind the interface to a single port or VLAN.

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Note Interfaces bound to a single port go down when the port goes down but interfaces bound to a VLAN remain up as long as at least one port in that VLAN remains active.

The procedure for creating an IPX interface depends on whether you are binding that interface to a single port or a VLAN. Separate discussions on the different procedures follow.

Note You cannot assign IPX interfaces for LAN and WAN to the same VLAN. In order for these two types of IPX interfaces to coexist on the RS, each type must be assigned to different VLANs.

23.3.4 IPX Addresses

The IPX address is a 12-byte number divided into three parts. The first part is the 4-byte (8-character) IPX external network number. The second part is the 6-byte (12-character) node number. The third part is the 2-byte (4-character) socket number.

23.4 CONFIGURING IPX INTERFACES AND PARAMETERS

This section provides an overview of configuring various IPX parameters and setting up IPX interfaces.

23.4.1 Configuring IPX Addresses to Ports

You can configure one IPX interface directly to a physical port.

To configure an IPX interface to a port, enter the following command in Configure mode:

Configure an IPX interface to a physical port.	**`interface create ipx`** *<InterfaceName>* **`address-mask`** *<ipxAddr-mask>* **`port`** *<port>*

23.4.2 Configuring Secondary Addresses on an IPX Interface

You can configure secondary addresses on an IPX interface.

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To configure a secondary address on an IPX interface, enter the following command in Configure mode:

Add a secondary address and encapsulation type to an existing IPX interface.	**interface add ipx** *<Interface Name>* **address** *<IPX-network-address>* **output-mac-encapsulation** *<encapsulation-type>*

Note Configuring a secondary address on an IPX interface requires updated RS hardware.

23.4.3 Configuring IPX Interfaces for a VLAN

You can configure one IPX interface per VLAN.

To configure a VLAN with an IPX interface, enter the following command in Configure mode:

Create an IPX interface for a VLAN.	**interface create ipx** *<InterfaceName>* **address-mask** *<ipxAddr-mask>* **vlan** *<name>*

23.4.4 Specifying IPX Encapsulation Method

The Riverstone RS Switch Router supports four encapsulation types for IPX. You can configure encapsulation type on a per-interface basis.

Ethernet II	The standard ARPA Ethernet version 2.0 encapsulation, which uses a 16-bit protocol type code (the default encapsulation method)
802.3 SNAP	SNAP IEEE 802.3 encapsulation, in which the type code becomes the frame length for the IEEE 802.2 LLC encapsulation (destination and source Service Access Points, and a control byte)
802.3	802.3 encapsulation method used within Novell IPX environments
802.2	802.2 encapsulation method used within Novell IPX environments

To configure IPX encapsulation, enter the following commands in Configure mode:

Configure Ethernet II encapsulation.	**interface create ipx** *<Interface Name>* **output-mac-encapsulation ethernet_II**
Configure 802.3 SNAP encapsulation.	**interface create ipx** *<Interface Name>* **output-mac-encapsulation ethernet_snap**

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Configure 802.3 IPX encapsulation.	**interface create ipx** *<Interface Name>* **output-mac-encapsulation ethernet_802.3**
Configure 802.2 IPX encapsulation.	**interface create ipx** *<Interface Name>* **output-mac-encapsulation ethernet_802.2_ipx**

23.5 CONFIGURING IPX ROUTING

By default, IPX routing is enabled on the RS.

23.5.1 Enabling IPX RIP

IPX RIP is enabled by default on the RS. You must first create an IPX interface or assign an IPX interface to a VLAN before RIP will start learning routes.

23.5.2 Enabling SAP

IPX SAP is enabled by default on the RS. You must first create an IPX interface or assign an IPX interface to a VLAN before SAP will start learning services.

23.5.3 Configuring Static Routes

In a Novell NetWare network, the RS uses RIP to determine the best paths for routing IPX. However, you can add static RIP routes to RIP routing table to explicitly specify a route.

To add a static RIP route, enter the following command in Configure mode:

Add a static RIP route.	**ipx add route** *<networkaddr> <nextrouter or network node> <metric> <ticks>*

23.5.4 Configuring Static SAP Table Entries

Servers in an IPX network use SAP to advertise services via broadcast packets. Services from servers are stored in the Server Information Table. If you want to have a service explicitly advertised with different hops, you will need to configure a static entry.

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To add an entry into the Server Information Table, enter the following command in Configure mode:

Add a SAP table entry.	**ipx add sap** <*service type*> <*SrvcName*> <*node*> <*socket*> <*metric*> <*interface-network*>

23.5.5 Controlling Access to IPX Networks

To control access to IPX networks, you create access control lists and then apply them with filters to individual interfaces. The RS supports the following IPX access lists that you can use to filter various kinds of traffic:

- IPX access control list: Restrict traffic based on the source address, destination address, source socket, destination socket, source network mask or destination network mask.
- SAP access control list: Restricts advertisements or learning of SAP services. These lists are used for SAP filters. They can also be used for Get Nearest Server (GNS) replies.
- RIP access control list: Restricts advertisements or learning of networks.

Creating an IPX Access Control List

IPX access control lists control which IPX traffic is received from or sent to an interface based on source address, destination address, source socket, destination socket, source network mask or destination network mask. This is used to permit or deny traffic from one IPX end node to another.

To create an IPX access control list, perform the following task in the Configure mode:

Create an IPX access control list.	**acl** <*name*> **permit|deny ipx** <*SrcNetwork Node*> <*DstNetworkNode*> <*SrcSocket*> <*SrcNetMask*> <*DstSocket*> <*DstNetMask*>

Once an IPX access control list has been created, you must apply the access control list to an IPX interface. To apply an IPX access control list, enter the following command in Configure mode:

Apply an IPX access control list.	**acl** <*name*> **apply interface** <*Interface Name*> **input|output [logging [on|off]]**

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Creating an IPX Type 20 Access Control List

IPX type 20 access control lists control the forwarding of IPX type 20 packets. To create an IPX type 20 access control list, enter the following command in Configure mode:

Create an IPX type 20 access control list.	**acl** <*name*> **permit|deny ipxtype20**

Creating an IPX SAP Access Control List

IPX SAP access control lists control which SAP services are available on a server. To create an IPX SAP access control list, enter the following command in Configure mode:

Create an IPX SAP access control list.	**acl** <*name*> **permit|deny ipxsap** <*ServerNetworkNode*> <*ServiceType*> <*ServiceName*>

Once an IPX SAP access control list has been created, you must apply the access control list to an IPX interface. To apply an IPX SAP access control list, enter the following command in Configure mode:

Apply an IPX SAP access control list.	**acl** <*name*> **apply interface** <*InterfaceName*> **input|output [logging [on|off]]**

Creating an IPX GNS Access Control List

IPX GNS access control lists control which SAP services the RS can reply with to a get nearest server (GNS) request. To create an IPX GNS access control list, enter the following command in Configure mode:

Create an IPX GNS access control list.	**acl** <*name*> **permit|deny ipxgns** <*ServerNetworkNode*> <*ServiceType*> <*ServiceName*>

Once an IPX GNS access control list has been created, you must apply the access control list to an IPX interface. To apply an IPX GNS access control list, enter the following command in Configure mode:

Apply an IPX GNS access control list.	**acl** <*name*> **apply interface** <*InterfaceName*> **output [logging [on|off]]**

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Creating an IPX RIP Access Control List

IPX RIP access control lists control which RIP updates are allowed. To create an IPX RIP access control list, perform the following task in the Configure mode:

Create an IPX RIP access control list.	**acl** <*name*> **permit|deny ipxrip** <*FromNetwork*> <*ToNetwork*>

Once an IPX RIP access control list has been created, you must apply the access control list to an IPX interface. To apply an IPX RIP access control list, enter the following command in Configure mode:

Apply an IPX RIP access control list.	**acl** <*name*> **apply interface** <*Interface Name*> **input|output [logging [on|off]]**

23.6 MONITORING AN IPX NETWORK

The RS reports IPX interface information and RIP or SAP routing information.

To display IPX information, enter the following command in Enable mode:

Show a RIP entry in the IPX RIP table.	**ipx find rip** <*DstNetwork*>
Show a SAP entry in the IPX SAP table.	**ipx find sap** <*type*> <*ServiceType*> <*ServiceName*> <*ServerNetwork*>
Show IPX interface information.	**ipx show interfaces** <*interface-name*>
Show IPX RIP table.	**ipx show tables rip**
Show IPX routing table.	**ipx show tables routing**
Show IPX SAP table.	**ipx show tables sap**
Show IPX RIP/SAP table summary.	**ipx show tables summary**

23.7 CONFIGURATION EXAMPLES

This example performs the following configuration:

- Creates IPX interfaces
- Adds static RIP routes
- Adds static SAP entries

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- Adds a RIP access list
- Adds a SAP access list
- Adds a GNS access list

```
! Create interface ipx1 with ipx address AAAAAAAA
interface create ipx ipx1 address AAAAAAAA port et.1.1 output-mac-encapsulation
ethernet_802.2_IPX
!
! Create interface ipx2 with ipx address BBBBBBBB
interface create ipx ipx2 address BBBBBBBB port et.1.2 output-mac-encapsulation
ethernet_802.3
!
! Add secondary address on interface ipx2 with ipx address CCCCCCCC
interface add ipx ipx2 address CCCCCCCC output-mac-encapsulation ethernet_II
!
!Add static route to network 9
ipx add route 9 BBBBBBBB.01:02:03:04:05:06 1 1
!
!Add static sap
ipx add sap 0004 FILESERVER1 9.03:04:05:06:07:08 452 1 AAAAAAAA
!
!RIP Access List
acl 100 deny ipxrip 1 2
!
!RIP inbound filter
acl 100 apply interface ipx1 input
!
!SAP Access List
acl 200 deny ipxsap A.01:03:05:07:02:03 0004 FILESERVER2
!
!SAP outbound filter to interface ipx2
acl 200 apply interface ipx2 output
!
!IPX type 20 access list
acl 300 deny ipxtype20
!
!IPX type 20 inbound filter to interface ipx2
acl 300 apply interface ipx2 input
!
!GNS Access List
acl 300 deny ipxgns A.01:03:05:07:02:03 0004 FILESERVER2
acl 200 apply interface ipx2 output
```


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24 ACCESS CONTROL LIST CONFIGURATION

This chapter explains how to configure and use Access Control Lists (ACLs) on the RS. ACLs are lists of selection criteria for specific types of packets. When used in conjunction with certain RS functions, ACLs allow you to restrict Layer-3/4 traffic going through the router.

This chapter contains the following sections:

- Section 24.1, *"ACL Basics,"* explains how ACLs are defined and how the RS evaluates them.
- Section 24.2, *"Creating and Modifying ACLs,"* describes how to edit ACLs, either remotely or by using the the RS's built-in ACL Editor function.
- Section 24.3, *"Using ACLs,"* describes the different kinds of ACLs: Interface ACLs, Service ACLs, Layer-4 Bridging ACLs, and Profile ACLs, and gives examples of their usage.
- Section 24.4, *"Enabling ACL Logging,"* explains how to log information about packets that are permitted or denied because of an ACL.
- Section 24.5, *"Monitoring ACLs,"* lists the commands you can use to display information about ACLs active on the RS.

24.1 ACL BASICS

An ACL consists of one or more *rules* describing a particular type of IP or IPX traffic. ACLs can be simple, consisting of only one rule, or complicated with many rules. Each rule tells the RS to either permit or deny packets that match selection criteria specified in the rule.

Each ACL is identified by a name. The name can be a meaningful string, such as **`denyftp`** or **`noweb`** or it can be a number such as **`100`** or **`101`**.

For example, the following ACL has a rule that permits all IP packets from subnet 10.2.0.0/16 to go through the RS:

```
acl 101 permit ip 10.2.0.0/16
```

24.1.1 Defining Selection Criteria in ACL Rules

Selection criteria in the rule describe characteristics about a packet. In the example above, the selection criteria are IP packets from 10.2.0.0/16.

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The selection criteria you can specify in an ACL rule depends on the type of ACL you are creating. For IP, TCP, and UDP ACLs, the following selection criteria can be specified:

- Source IP address
- Destination IP address
- Source port number
- Destination port number
- Type of Service (TOS)
- The **accounting** keyword specifies that LFAP accounting information about the flows that match the 'permit' rule are sent to the configured Flow Accounting Server (FAS). See Chapter 29, *"LFAP Configuration Guide"*, for more information.

Note The **accounting** parameter must be followed by one of the three *checkpoint* time interval parameters: **5-minutes**, **15-minutes**, or **hourly**.

For IPX ACLs, the following selection criteria can be specified:

- Source network address
- Destination network address
- Source IPX socket
- Destination IPX socket

These selection criteria are specified as *fields* of an ACL rule. The following syntax description shows the fields of an IP ACL rule:

```
acl <name> permit|deny ip <SrcAddr/Mask> <DstAddr/Mask> <SrcPort> <DstPort> <tos> <tos-mask>
[accounting] <checkpoint interval>
```

Note The **acl permit|deny ip** command restricts traffic for all IP-based protocols, such as TCP, UDP, ICMP, and IGMP. Variants of the **acl permit|deny ip** command exist that allow you to restrict traffic for a specific IP-based protocol; for example, the **acl permit|deny tcp** command lets you restrict only TCP traffic. These variants have the same syntax and fields as the **acl permit|deny ip** command.

The following syntax description shows the fields of an IPX ACL rule:

```
acl <name> permit|deny ipx <SrcAddr> <SrcSocket> <DstAddr> <DstSocket> <SrcNetMask>
<DstNetMask>
```


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Each field in an ACL rule is position sensitive. For example, for a rule for TCP traffic, the source address must be followed by the destination address, followed by the source socket and the destination socket, and so on.

Not all fields of an ACL rule need to be specified. If a particular field is not specified, it is treated as a wildcard or "don't care" condition. However, if a field is specified, that particular field will be matched against the packet. Each protocol can have a number of different fields to match. For example, a rule for TCP can use socket port numbers, while a rule for IPX can use a network node address.

Since each field is position sensitive, it may be necessary to "skip" some fields in order to specify a value for another field. To skip a field, use the keyword **any**. For example, the following ACL rule denies SMTP traffic between any two hosts:

```
acl nosmtp deny tcp any any smtp smtp
```

Note that in the above example, the <*tos*> (Type of Service) field is not specified and is treated as a wildcard. The **any** keyword is needed only to skip a wildcard field in order to explicitly specify another field that is further down in the rule. If there are no other fields to specify, the **any** keyword is not necessary. For example, the following ACL permits all IP traffic to go through:

```
acl yesip permit ip
```

24.1.2 How ACL Rules are Evaluated

For an ACL with multiple rules, the ordering of the rules is important. When the RS checks a packet against an ACL, it goes through each rule in the ACL sequentially. If a packet matches a rule, it is forwarded or dropped based on the **permit** or **deny** keyword in the rule. All subsequent rules are ignored. That is, a first-match algorithm is used. There is no hidden or implied ordering of ACL rules, nor is there precedence attached to each field. The RS simply goes down the list, one rule at a time, until there is a match. Consequently, rules that are more specific (that is, with more selection criteria) should always be listed ahead of rules that are less specific. For example, the following ACL permits all TCP traffic except those from subnet 10.2.0.0/16:

```
acl 101 deny tcp 10.2.0.0/16 any any any
acl 101 permit tcp any any any any
```

When a TCP packet comes from subnet 10.2.0.0/16, it finds a match with the first rule. This causes the packet to be dropped. A TCP packet coming from other subnets does not match the first rule. Instead, it matches the second rule, which allows the packet to go through.

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If you were to reverse the order of the two rules:

```
acl 101 permit tcp any any any any
acl 101 deny tcp 10.2.0.0/16 any any any
```

all TCP packets would be allowed to go through, including traffic from subnet 10.2.0.0/16. This is because TCP traffic coming from 10.2.0.0/16 would match the first rule and be allowed to go through. The second rule would not be looked at since the first match determines the action taken on the packet.

24.1.3 Implicit Deny Rule

At the end of each ACL, the system automatically appends an *implicit deny rule*. This implicit deny rule denies all traffic. For a packet that doesn't match any of the user-specified rules, the implicit deny rule acts as a catch-all rule. All packets match this rule.

This is done for security reasons. If an ACL is misconfigured, and a packet that should be allowed to go through is blocked because of the implicit deny rule, the worst that could happen is inconvenience. On the other hand, if a packet that should not be allowed to go through is instead sent through, there is now a security breach. Thus, the implicit deny rule serves as a line of defense against accidental misconfiguration of ACLs.

To illustrate how the implicit deny rule is used, consider the following ACL:

```
acl 101 permit ip 1.2.3.4/24
acl 101 permit ip 4.3.2.1/24 any nntp
```

With the implicit deny rule, this ACL actually has three rules:

```
acl 101 permit ip 1.2.3.4/24 any any any
acl 101 permit ip 4.3.2.1/24 any nntp any
acl 101 deny any any any any any
```

If a packet comes in and doesn't match the first two rules, the packet is dropped. This is because the third rule (the implicit deny rule) matches all packets.

Although the implicit deny rule may seem obvious in the above example, this is not always the case. For example, consider the following ACL rule:

```
acl 102 deny ip 10.1.20.0/24 any any any
```


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If a packet comes in from a network other than 10.1.20.0/24, you might expect the packet to go through because it doesn't match the first rule. However, that is not the case because of the implicit deny rule. With the implicit deny rule attached, the rule looks like this:

```
acl 102 deny ip 10.1.20.0/24 any any any
acl 102 deny any any any any any
```

A packet coming from 10.1.20.0/24 would not match the first rule, but would match the implicit deny rule. As a result, no packets would be allowed to go through. The first rule is simply a subset of the second rule. To allow packets from subnets other than 10.1.20.0/24 to go through, you would have to explicitly define a rule to permit other packets to go through.

To correct the above example and let packets from other subnets enter the RS, you must add a new rule to permit packets to go through:

```
acl 101 deny ip 10.1.20.0/24 any any any
acl 101 permit ip
acl 101 deny any any any any any
```

The second rule forwards all packets that are not denied by the first rule.

Because of the implicit deny rule, an ACL works similarly to a firewall that is elected to deny all traffic. You create ACL rules that punch "holes" into the firewall to permit specific types of traffic; for example, traffic from a specific subnet or traffic from a specific application.

24.1.4 Allowing External Responses to Established TCP Connections

Typically organizations that are connected to the outside world implement ACLs to deny access to the internal network. If an internal user wishes to connect to the outside world, the request is sent; however any incoming replies may be denied because ACLs prevent them from going through. To allow external responses to internally generated requests, you would have to create an ACL to allow responses from each specific outside host. If the number of outside hosts that internal users need to access is large or changes frequently, this can be difficult to maintain.

To address this problem, the RS can be configured to accept outside TCP responses into the internal network, provided that the TCP connection was initiated internally. Otherwise, it will be rejected. To do this, enter the following command in Configure Mode:

Allow TCP responses from external hosts, provided the connection was established internally.	**acl** <*name*> **permit tcp established**

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Note The ports that are associated with the interface to which the ACL is applied must reside on updated RS hardware.

The following ACL illustrates this feature:

```
acl 101 permit tcp established
acl 101 apply interface int1 input
```

Any incoming TCP packet on interface int1 is examined, and if the packet is in response to an internal request, it is permitted; otherwise, it is rejected. Note that the ACL contains no restriction for outgoing packets on interface int1, since internal hosts are allowed to access the outside world.

24.2 CREATING AND MODIFYING ACLS

The RS provides two mechanisms for creating and modifying ACLs:

- Editing ACLs on a remote host and uploading them to to the RS using TFTP or RCP
- Using the RS's ACL Editor

The following sections describe these methods.

24.2.1 Editing ACLs Offline

You can create and edit ACLs on a remote host and then upload them to the RS with TFTP or RCP. With this method, you use a text editor on a remote host to edit, delete, replace, or reorder ACL rules in a file. Once the changes are made, you can then upload the ACLs to the RS using TFTP or RCP and make them take effect on the running system. The following example describes how you can use TFTP to help maintain ACLs on the RS.

Suppose the ACL '101' is already defined and applied to an interface on the RS. To modify the ACL by uploading text files, you will need to first negate the commands that define and apply the ACL 101. For example, the following command stored in the text file **acl.no** will be used to negate commands related to the ACL 101:

```
no acl 101*
```

The command **no acl 101*** negates all commands that start with "acl 101." This tells the RS to remove the application and the definition of ACL 101. (If you want to remove all ACL commands, enter **no acl *.**) The negation of all related ACL commands is important because it removes any potential confusion caused by the addition of new ACL rules to existing rules. Basically, the **no acl** command cleans up the system for the new ACL rules.

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The following ACL commands stored the text file **acl.changes** will be used to redefine ACL 101 and apply the ACL to interface int12:

```
acl 101 deny tcp 10.11.0.0/16 10.12.0.0/16
acl 101 permit tcp 10.11.0.0 any
acl 101 apply interface int12 input
```

If the changes are accessible from a TFTP server, you can upload and make the changes take effect by issuing commands like the following:

```
rs# copy tftp://10.1.1.12/config/acl.no to scratchpad
rs# copy scratchpad to active
rs# copy tftp://10.1.1.12/config/acl.changes to scratchpad
rs# copy scratchpad to active
```

The first **copy** command uploads the file **acl.no** from a TFTP server and puts the commands into the temporary configuration area, the scratchpad. The second **copy** command makes the **no acl** command take effect by copying from the scratchpad to the active running system, in this case negating all the commands that define and apply ACL 101. The third **copy** command uploads the file **acl.changes** from the TFTP server to the scratchpad. (You can re-examine the changes if necessary before committing the changes to the running system.) The last **copy** command makes the changes take effect by copying commands from the scratchpad to the active running system.

If you need to re-order or modify the ACL rules, you must make the changes in the files on the remote host, upload the changes, and make them effective again.

24.2.2 Maintaining ACLs Using the ACL Editor

In addition to the method of maintaining ACLs using TFTP or RCP, the RS provides a simpler and more user-friendly mechanism to maintain ACLs: the ACL editor. The ACL editor is a facility that is used "online," that is, via CLI on a Console or Telnet session.

The ACL Editor can only be accessed within Configure mode using the **acl-edit** command. You edit an ACL by specifying its name together with the **acl-edit** command. For example, to edit ACL 101, you issue the command **acl-edit 101**. The only restriction is that when you edit a particular ACL, you cannot add rules for a different ACL. You can only add new rules for the ACL that you are currently editing. When the editing session is over, that is, when you are done making changes to the ACL, you can save the changes and make them take effect immediately. Within the ACL editor, you can add new rules (**add** command), delete existing rules (**delete** command) and re-order the rules (**move** command). To save the changes, use the **save** command or simply exit the ACL Editor.

If you edit and save changes to an ACL that is currently being used or applied to an interface, the changes will take effect immediately. There is no need to remove the ACL from the interface before making changes and reapply it after changes are made. The process is automatic.

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24.3 USING ACLS

It is important to understand that an ACL is simply a definition of packet characteristics specified in a set of rules. An ACL must be *enabled* in one of the following ways:

- Applying an ACL to an interface, which permits or denies traffic to or from the RS. ACLs used in this way are known as *interface ACLs*.
- Applying an ACL to a service, which permits or denies access to system services provided by the RS. ACLs used in this way are known as *service ACLs*.
- Applying an ACL to ports operating in Layer-4 bridging mode, which permits or denies bridged traffic. ACLs used in this way are known as *layer-4 Bridging ACLs*.
- Associating an ACL with **`ip-policy`**, **`nat`**, **`port mirroring`**, **`rate-limit`**, or **`web-cache`** commands, which specifies the criteria that packets, addresses, or flows must meet in order to be relevant to these RS features. ACLs used in this way are known as *profile ACLs*.

These uses of ACLs are described in the following sections.

24.3.1 Applying ACLs to Interfaces

An ACL can be applied to an interface to examine either inbound or outbound traffic. Inbound traffic is traffic coming into the RS. Outbound traffic is traffic going out of the RS. For each interface, only one ACL can be applied for the same protocol in the same direction. For example, you cannot apply two or more IP ACLs to the same interface in the inbound direction. You can apply two ACLs to the same interface if one is for inbound traffic and one is for outbound traffic, but not in the same direction. However, this restriction does not prevent you from specifying many rules in an ACL. You just have to put all of these rules into one ACL and apply it to an interface.

When a packet comes into the RS at an interface where an inbound ACL is applied, the RS compares the packet to the rules specified by that ACL. If it is permitted, the packet is allowed into the RS. If not, the packet is dropped. If that packet is to be forwarded to go out of another interface (that is, the packet is to be routed) then a second ACL check is possible. At the output interface, if an outbound ACL is applied, the packet will be compared to the rules specified in this outbound ACL. Consequently, it is possible for a packet to go through two separate checks, once at the inbound interface and once more at the outbound interface.

When you apply an ACL to an interface, you can also specify whether the ACL can be modified or removed from the interface by an external agent (such as the Policy Manager application). Note that for an external agent to modify or remove an applied ACL from an interface, the **`acl-policy enable external`** command must be in the configuration.

In general, you should try to apply ACLs at the inbound interfaces instead of the outbound interfaces. If a packet is to be denied, you want to drop the packet as early as possible, at the inbound interface. Otherwise, the RS will have to process the packet, determine where the packet should go only to find out that the packet should be dropped at the outbound interface. In some cases, however, it may not be simple or possible for the administrator to know ahead of time that a packet should be dropped at the inbound interface. Nonetheless, for performance reasons, whenever possible, you should create and apply an ACL to the inbound interface.

To apply an ACL to an interface, enter the following command in Configure mode:

Apply ACL to an interface.	**`acl`** <*name*> **`apply interface`** <*interface name*> **`input|output [logging on|off|deny-only|permit-only][policy local|external]`**

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24.3.2 Applying ACLs to Services

ACLs can also be created to permit or deny access to system services provided by the RS; for example, HTTP or Telnet servers. This type of ACL is known as a *Service* ACL. By definition, a Service ACL is for controlling inbound packets to a service on specific interfaces on the router. For example, on a particular interface, you can grant Telnet server access from a few specific hosts or deny Web server access from a particular subnet. It is true that you can do the same thing with ordinary ACLs and apply them to specific interfaces. However, the Service ACL is created specifically to control access to some of the services on specified interfaces of the RS. As a result, only inbound traffic to the RS is checked.

Note If a service does not have an ACL applied, that service is accessible to everyone. To control access to a service, an ACL must be used.

To apply an ACL to a service, enter the following command in Configure mode:

Apply ACL to a service.	**acl** <*name*> **apply service** <*service name*> **[logging [on|off]]**

24.3.3 Applying ACLs to Layer-4 Bridging Ports

ACLs can also be created to permit or deny access to one or more ports operating in Layer-4 bridging mode. Traffic that is switched at Layer 2 through the RS can have ACLs applied on the Layer 3/4 information contained in the packet. The ACLs that are applied to Layer-4 Bridging ports are only used with bridged traffic. The ACLs that are applied to the interface are still used for routed traffic.

Like ACLs that are applied to interfaces, ACLs that are applied to Layer 4 bridging ports can be applied to either inbound or outbound traffic. For each port, only one ACL can be applied for the inbound direction and one for the outbound direction. You can apply two ACLs to the same port if one is for inbound traffic and one is for outbound traffic.

To apply an ACL to a port, enter the following command in Configure Mode:

Apply a Layer-4 bridging ACL to a port	**acl** <*name*> **apply port** <*port-list*>

See Section 25.4, *"Layer-4 Bridging and Filtering,"* for information on configuring Layer-4 Bridging on the RS.

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24.3.4 Using ACLs as Profiles

You can use the **acl** command to define a *profile*. A profile specifies the criteria that addresses, flows, hosts, or packets must meet to be relevant to certain RS features. Once you have defined an ACL profile, you can use the profile with the configuration command for that feature. For example, the Network Address Translation (NAT) feature on the RS allows you to create address pools for dynamic bindings. You use ACL profiles to represent the appropriate pools of IP addresses.

The following RS features use ACL profiles:

Table 24-1 Features that use ACl profile

RS Feature	ACL Profile Usage
IP policy	Specifies the packets that are subject to the IP routing policy.
Dynamic NAT	Defines local address pools for dynamic bindings.
Port mirroring	Defines traffic to be mirrored.
Rate limiting	Specifies the incoming traffic flow to which rate limiting is applied.
Web caching	Specifies which HTTP traffic should always (or never) be redirected to the cache servers. Specifies characteristics of Web objects that should not be cached.

Note the following about using profile ACLs:

- Only IP ACLs can be used as Profile ACLs. ACLs for non-IP protocols *cannot* be used as Profile ACLs.
- The **permit/deny** keywords, while required in the ACL rule definition, are *disregarded* in the configuration commands for the above-mentioned features. In other words, the configuration commands will act upon a specified Profile ACL whether or not the Profile ACL rule contains the **permit** or **deny** keyword.
- Only certain ACL rule parameters are relevant for each configuration command. For example, the configuration command to create NAT address pools for dynamic bindings (the **nat create dynamic** command) only looks at the source IP address in the specified ACL rule. The destination IP address, ports, and TOS parameters, if specified, are ignored.

Specific usage of Profile ACLs is described in more detail in the following sections.

Using Profile ACLs with the IP Policy Facility

The IP policy facility uses a Profile ACL to define criteria that determines which packets should be forwarded according to an IP policy. Packets that meet the criteria defined in the Profile ACL are forwarded according to the **ip-policy** command that references the Profile ACL.

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For example, you can define an IP policy that causes all telnet packets travelling from source network 9.1.1.0/24 to destination network 15.1.1.0/24 to be forwarded to destination address 10.10.10.10. You use a Profile ACL to define the selection criteria (in this case, telnet packets travelling from source network 9.1.1.0/24 to destination network 15.1.1.0/24). Then you use an **ip-policy** command to specify what happens to packets that match the selection criteria (in this example, forward them to address 10.10.10.10). The following commands illustrate this example.

This command creates a Profile ACL called *prof1* that uses as its selection criteria all telnet packets travelling from source network 9.1.1.0/24 to destination network 15.1.1.0/24:

```
rs(config)# acl prof1 permit ip 9.1.1.0/24 15.1.1.0/24 any any telnet 0
```

This Profile ACL is then used in conjunction with the **ip-policy** command to cause packets matching prof1's selection criteria (that is, telnet packets travelling from 9.1.1.0/24 to 15.1.1.0/24) to be forwarded to 10.10.10.10:

```
rs(config)# ip-policy p5 permit profile prof1 next-hop-list 10.10.10.10
```

See Chapter 20, *"IP Policy-Based Forwarding Configuration"* for more information on using the **ip-policy** command.

Using Profile ACLs with the Traffic Rate Limiting Facility

Traffic rate limiting is a mechanism that allows you to control bandwidth usage of incoming traffic on a per-flow basis. A flow meeting certain criteria can have its packets re-prioritized or dropped if its bandwidth usage exceeds a specified limit.

For example, you can cause packets in flows from source address 1.2.2.2 to be dropped if their bandwidth usage exceeds 10 Mbps. You use a Profile ACL to define the selection criteria (in this case, flows from source address 1.2.2.2). Then you use a **rate-limit** command to specify what happens to packets that match the selection criteria (in this example, drop them if their bandwidth usage exceeds 10 Mbps). The following commands illustrate this example.

This command creates a Profile ACL called *prof2* that uses as its selection criteria all packets originating from source address 1.2.2.2:

```
rs(config)# acl prof2 permit ip 1.2.2.2
```


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The following command creates a *rate limit definition* that causes flows matching Profile ACL prof2's selection criteria (that is, traffic from 1.2.2.2) to be restricted to 10 Mbps for each flow. If this rate limit is exceeded, the packets are dropped.

```
rs(config)# rate-limit client1 input acl prof2 rate-limit 10000000 exceed-action
drop-packets
```

When the rate limit definition is applied to an interface (with the **rate-limit apply interface** command), packets in flows originating from source address 1.2.2.2 are dropped if their bandwidth usage exceeds 10 Mbps.

Using Profile ACLs with Dynamic NAT

Network Address Translation (NAT) allows you to map an IP address used within one network to a different IP address used within another network. NAT is often used to map addresses used in a private, local intranet to one or more addresses used in the public, global Internet.

The RS supports two kinds of NAT: *static* NAT and *dynamic* NAT. With dynamic NAT, an IP address within a range of local IP addresses is mapped to an IP address within a range of global IP addresses. For example, you can configure IP addresses on network 10.1.1.0/24 to use an IP address in the range of IP addresses in network 192.50.20.0/24. You can use a Profile ACL to define the ranges of local IP addresses.

The following command creates a Profile ACL called *local*. The local profile specifies as its selection criteria the range of IP addresses in network 10.1.1.0/24..

```
rs(config)# acl local permit ip 10.1.1.0/24
```

Note When a Profile ACL is defined for dynamic NAT, only the source IP address field in the **acl** statement is evaluated. All other fields in the **acl** statement are ignored.

Once you have defined a Profile ACL, you can then use the **nat create dynamic** command to bind the range of IP addresses defined in the local profile to a range in network 192.50.20.0/24.

```
rs(config)# nat create dynamic local-acl-pool local global-pool 192.50.20.10/24
```

See Chapter 21, *"Network Address Translation Configuration"* for more information on using dynamic NAT.

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Using Profile ACLs with the Port Mirroring Facility

Port mirroring refers to the RS's ability to copy traffic on one or more ports to a "mirror" port, where an external analyzer or probe can be attached. In addition to mirroring traffic on one or more ports, the RS can mirror traffic that matches selection criteria defined in a Profile ACL.

For example, you can mirror all IGMP traffic on the RS. You use a Profile ACL to define the selection criteria (in this example, all IGMP traffic). Then you use a **port mirroring** command to copy packets that match the selection criteria to a specified mirror port. The following commands illustrate this example.

This command creates a Profile ACL called *prof3* that uses as its selection criteria all IGMP traffic on the RS:

```
rs(config)# acl prof3 permit igmp
```

The following command causes packets matching Profile ACL prof3's selection criteria (that is, all IGMP traffic) to be copied to mirror port et.1.2.

```
rs(config)# port mirroring monitor-port et.1.2 target-profile prof3
```

See Section 27.1, *"Configuring the RS for Port Mirroring,"* for more information on using the **port mirroring** command.

Using Profile ACLs with the Web Caching Facility

Web caching is the RS's ability to direct HTTP requests for frequently accessed Web objects to local cache servers, rather than to the Internet. Since the HTTP requests are handled locally, response time is faster than if the Web objects were retrieved from the Internet.

You can use Profile ACLs with Web caching in two ways:

- Specifying which HTTP traffic should always (or never) be redirected to the cache servers
- Specifying characteristics of Web objects that should not be cached

You can use a Profile ACL to specify which HTTP traffic should always (or never) be redirected to the cache servers. (By default, when Web caching is enabled, all HTTP traffic from all hosts is redirected to the cache servers unless you specify otherwise.)

For example, you can specify that packets with a source address of 10.10.10.10 and a destination address of 1.2.3.4 always are sent to the Internet and never to the cache servers. The following commands illustrate this example.

This command creates a Profile ACL called *prof4* that uses as its selection criteria all packets with a source address of 10.10.10.10 and a destination address of 1.2.3.4 :

```
rs(config)# acl prof4 permit ip 10.10.10.10 1.2.3.4
```


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The following command creates a *Web caching policy* that prevents packets matching Profile ACL prof4's selection criteria (that is, packets with a source address of 10.10.10.10 and a destination address of 1.2.3.4) from being redirected to a cache server. Packets that match the profile's selection criteria are sent to the Internet instead.

```
rs(config)# web-cache policy1 deny hosts profile prof4
```

When the Web caching policy is applied to an interface (with the **web-cache apply interface** command), HTTP traffic with a source address of 10.10.10.10 and a destination address of 1.2.3.4 goes to the Internet instead of to the cache servers.

You can also use a Profile ACL to prevent certain Web objects from being cached. For example, you can specify that information in packets originating from Internet site 1.2.3.4 and destined for local host 10.10.10.10 not be sent to the cache servers. The following commands illustrate this example.

This command creates a Profile ACL called *prof5* that uses as its selection criteria all packets with a source address of 1.2.3.4 and a destination address of 10.10.10.10:

```
rs(config)# acl prof5 permit ip 1.2.3.4 10.10.10.10
```

To have packets matching Profile ACL prof5's selection criteria bypass the cache servers, use the following command:

```
rs(config)# web-cache policy1 create bypass-list profile prof5
```

When the Web caching policy is applied to an interface, information in packets originating from source address 1.2.3.4 and destined for address 10.10.10.10 is not sent to the cache servers.

See Section 22.2, *"Web Caching,"* for more information on using the **web-cache** command.

24.4 ENABLING ACL LOGGING

To see whether incoming packets are permitted or denied because of an ACL, you can enable ACL logging. You can enable logging when applying the ACL or you can enable logging for a specific ACL rule.

The following commands define an ACL and apply the ACL to an interface, with logging enabled for the ACL:

```
acl 101 deny ip 10.2.0.0/16 any any any
acl 101 permit ip any any any any
acl 101 apply interface int1 input logging on
```


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When ACL logging is turned on, the router prints out a message on the console about whether a packet is dropped *or* forwarded. If you have a Syslog server configured for the RS, the same information will also be sent to the Syslog server.

The following commands define an ACL and apply the ACL to an interface. In this case, logging is enabled for a specific ACL rule:

```
acl 101 deny ip 10.2.0.0/16 any any any log
acl 101 permit ip any any any any
acl 101 apply interface int1 input logging off
```

For the above commands, the router prints out messages on the console only when packets that come from subnet 10.2.0.0/16 on interface 'int1' are dropped.

Note If you want to enable per-rule logging, specify the **`logging off`** option for the **`acl apply`** command. This will enable logging only on the specified ACL rule instead of logging on all ACL rules applied to the interface.

Before enabling ACL logging, you should consider its impact on performance. With ACL logging enabled, the router prints out a message at the console before the packet is actually forwarded or dropped. Even if the console is connected to the router at a high baud rate, the delay caused by the console message is still significant. This can get worse if the console is connected at a low baud rate, for example, 1200 baud. Furthermore, if a Syslog server is configured, then a Syslog packet must also be sent to the Syslog server, creating additional delay. Therefore, you should consider the potential performance impact before turning on ACL logging.

24.5 MONITORING ACLS

The RS provides a display of ACL configurations active in the system.

To display ACL information, enter the following commands in Enable mode.

Show all ACLs.	**`acl show all`**
Show a specific ACL.	**`acl show aclname`** <*name*> **`| all`**
Show an ACL on a specific interface.	**`acl show interface`** <*name*>
Show ACLs on all IP interfaces.	**`acl show interface all-ip`**
Show static entry filters.	**`acl show service`**

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25 SECURITY CONFIGURATION

The RS provides security features that help control access to the RS and filter traffic going through the RS. Access to the RS can be controlled by:

- Enabling RADIUS
- Enabling TACACS
- Enabling TACACS+
- Password authentication
- Secure shell protocol

Traffic filtering on the RS enables:

- Layer-2 security filters - Perform filtering on source or destination MAC addresses.
- Layer-3/4 Access Control Lists - Perform filtering on source or destination IP address, source or destination TCP/UDP port, TOS or protocol type for IP traffic. Perform filtering on source or destination IPX address, or source or destination IPX socket. Perform access control to services provided on the RS, for example, Telnet server and HTTP server.

Note Currently, Source Filtering is available on RS WAN cards; however, application must take place on the entire WAN card.

25.1 CONFIGURING RS ACCESS SECURITY

This section describes the following methods of controlling access to the RS:

- RADIUS
- TACACS
- TACACS+
- Passwords
- Secure shell

25.1.1 Configuring RADIUS

You can secure login or Enable mode access to the RS by enabling a Remote Authentication Dial-In Service (RADIUS) client. A RADIUS server responds to the RS RADIUS client to provide authentication.

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You can configure up to five RADIUS server targets on the RS. A timeout is set to tell the RS how long to wait for a response from RADIUS servers.

Note Verify parameter values before saving radius commands to the active or startup configuration file on the RS. Any misconfiguration can effectively lock you out of the CLI.

To configure RADIUS security, enter the following commands in Configure mode:

Specify a RADIUS server and configure server-specific parameters.	**radius set server** *<IP-addr> <server-options>*
Set time that RADIUS server is ignored after it has failed.	**radius set deadtime** *<minutes>*
Set authentication key for RADIUS server.	**radius set key** *<string>*
Determine the RS action if there is no server response within a given time. [a]	**radius set last-resort password|succeed|deny**
Set the maximum number of times the RADIUS server is contacted for authentication.	**radius set retries** *<number>*
Set the source IP address or interface for use with RADIUS server.	**radius set source** *<ipaddr>*|*<interface>*
Set the maximum time to wait for a RADIUS server reply.	**radius set timeout** *<seconds>*
Enable RADIUS.	**radius enable**
Cause RADIUS authentication at user login or when user tries to access Enable mode.	**radius authentication login|enable**
Logs specified types of command to RADIUS server.	**radius accounting command level** *<level>*
Logs to RADIUS server when shell is stopped or started on RS.	**radius accounting shell start|stop|all**
Logs to RADIUS server SNMP changes to startup or active configuration.	**radius accounting snmp active|startup**
Logs specified type(s) of messages to RADIUS server.	**radius accounting system fatal|error|warning|info**

a. If this command is not specified, the RS tries the next configured authentication method (including TACACS+ configuration commands). Otherwise, if the server does not reply within the configured timeout period for the configured number of retries, user authentication will fail.

Monitoring RADIUS

You can monitor RADIUS configuration and statistics within the RS.

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To monitor RADIUS, enter the following commands in Enable mode:

Show RADIUS server statistics.	**radius show stats**
Show all RADIUS parameters.	**radius show all**

25.1.2 Configuring TACACS

In addition, Enable mode access to the RS can be made secure by enabling a Terminal Access Controller Access Control System (TACACS) client. Without TACACS, TACACS+, or RADIUS enabled, only local password authentication is performed on the RS. The TACACS client provides user name and password authentication for Enable mode. A TACACS server responds to the RS TACACS client to provide authentication.

You can configure up to five TACACS server targets on the RS. A timeout is set to tell the RS how long to wait for a response from TACACS servers.

To configure TACACS security, enter the following commands in the Configure mode:

Specify a TACACS server.	**tacacs set server** *<hostname or IP-addr>*
Set the TACACS time to wait for a TACACS server reply.	**tacacs set timeout** *<number>*
Determine RS action if no server responds.	**tacacs set last-resort password|succeed**
Enable TACACS.	**tacacs enable**

Monitoring TACACS

You can monitor TACACS configuration and statistics within the RS.

To monitor TACACS, enter the following commands in Enable mode:

Show TACACS server statistics.	**tacacs show stats**
Show all TACACS parameters.	**tacacs show all**

25.1.3 Configuring TACACS+

You can secure login or Enable mode access to the RS by enabling a TACACS+ client. A TACACS+ server responds to the RS TACACS+ client to provide authentication.

You can configure up to five TACACS+ server targets on the RS. A timeout is set to tell the RS how long to wait for a response from TACACS+ servers.

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To configure TACACS+ security, enter the following commands in Configure mode:

Specify a TACACS+ server and configure server-specific parameters.	**tacacs-plus set server** *<IP-addr> <server-options>*
Set time that TACACS+ server is ignored after it has failed.	**tacacs-plus set deadtime** *<minutes>*
Set authentication key for TACACS+ server.	**tacacs-plus set key** *<string>*
Determine the RS action if there is no server response within a given time. [a]	**tacacs-plus set last-resort password|succeed|deny**
Set the maximum number of times the TACACS+ server is contacted for authentication.	**tacacs-plus set retries** *<number>*
Set the source IP address or interface for use with TACACS+ server.	**tacacs-plus set source** *<ipaddr>*|*<interface>*
Set the maximum time to wait for a TACACS+ server reply.	**tacacs-plus set timeout** *<seconds>*
Enable TACACS+.	**tacacs-plus enable**
Cause TACACS+ authentication at user login or when user tries to access Enable mode.	**tacacs-plus authentication login|enable**
Logs specified types of command to TACACS+ server.	**tacacs-plus accounting command level** *<level>*
Logs to TACACS+ server when shell is stopped or started on RS.	**tacacs-plus accounting shell start|stop|all**
Logs to TACACS+ server SNMP changes to startup or active configuration.	**tacacs-plus accounting snmp active|startup**
Logs specified type(s) of messages to TACACS+ server.	**tacacs-plus accounting system fatal|error|warning|info**

a. If this command is not specified, the RS tries the next configured authentication method (including RADIUS configuration commands). Otherwise, if the server does not reply within the configured timeout period for the configured number of retries, user authentication will fail.

Monitoring TACACS+

You can monitor TACACS+ configuration and statistics within the RS.

To monitor TACACS+, enter the following commands in Enable mode:

Show TACACS+ server statistics.	**tacacs-plus show stats**
Show all TACACS+ parameters.	**tacacs-plus show all**

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25.1.4 Configuring Passwords

The RS provides password authentication for accessing the User and Enable modes. If TACACS, TACACS+, or RADIUS is not enabled on the RS, only local password authentication is performed.

To configure RS passwords, enter the following commands in Configure mode:

Set User mode password.	**system set password login** <*string*>
Set Enable mode password.	**system set password enable** <*string*>

25.1.5 Configuring SSH

Secure shell (SSH) is a protocol that allows you to log in to a remote RS and execute commands on that router. SSH provides more secure communications than using Telnet, as connections are authenticated and communications over the network are encrypted.

The RS provides both an SSH server and client. Both server and client support SSH version 1. Only username and password authentication (as configured with the CLI **system set password** command) is supported. If TACACS or RADIUS authentication is enabled on the router, passwords are authenticated by the TACACS or RADIUS server. Private and public keys on a per-user basis are *not* supported.

Establishing SSH Sessions

The SSH server on the RS must have a public key and a host key generated with the CLI **ssh server generate-key** command. The keys are generated using the Rivest-Shamir-Adleman (RSA) algorithm. For example, the following command generates RSA keys on the router ‘r1’:

```
r1# ssh server generate-key rsa
Your identification has been saved in /int-flash/cfg/ssh/ssh_host_key.
Your public key has been saved in /int-flash/cfg/ssh/ssh_host_key.pub.
```

On the RS, you use the **slogin** command in Enable mode to access a remote RS SSH server. In addition to specifying the hostname or host IP address of the RS, you can specify a username. The default username is **root**. You can optionally specify a port number on the router; the default port number is 22. For example, the following command allows you to log into the remote router ‘r1’ with the username ‘login’:

```
r2# slogin login@r1
```


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The SSH server on r1 responds with its public host and server keys. The client on r2 checks the received host key to make sure that the key has not changed since the last SSH session between the client and this server. If the host key is different from the host key used in the last SSH session with this server, you are asked if you want to continue to connect to the server. This is a precaution to ensure that the SSH client is connecting to the intended router.

To continue the server connection, the client then encrypts a random number using both the public host and server keys and sends the encrypted number to the SSH server. Both the SSH server and client will use this random number as a key to encrypt communications in their session.

If a login password has been configured on the RS, you will be prompted for it. Because communications between the SSH client and server is now encrypted within the SSH session, the password is secure from other users on the network. You can use CLI commands in the SSH session as you normally would through a Console or Telnet connection. You can also use the **slogin** command to access another SSH server on a remote RS.

To end your SSH session, simply type **exit**.

Note You can use any SSH version 1 client to access the SSH server on the RS. For example, there are several SSH clients available that run under Windows 95/98.

Monitoring SSH Sessions

The RS allows up to four simultaneous Telnet *or* SSH sessions. There are commands that allow you to monitor SSH use on the RS and to end a specific SSH session. You can also specify the number of minutes an SSH connection can remain idle before the connection is terminated by the control module. The default is 5 minutes. You can disable this feature, by setting the time-out value to zero.

Table 25-1 SSH session commands

Display the last five SSH connections to the RS.	**system show ssh-access**
Specify the time-out value for SSH connections.	**system set idle-time-out ssh** <*num*>
Show current Telnet and SSH users and session IDs.	**system show users**
End the specified SSH session.	**system kill ssh-session** <*session-id*>

25.2 LAYER-2 SECURITY FILTERS

Layer-2 security filters on the RS allow you to configure ports to filter specific MAC addresses. When defining a Layer-2 security filter, you specify to which ports you want the filter to apply. You can specify the following security filters:

Address filters	These filters block traffic based on the frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Address filters are always configured and applied to the input port.
Port-to-address lock filters	These filters prohibit a user connected to a locked port or set of ports from using another port.

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Static entry filters	These filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port.
Secure port filters	A secure filter shuts down access to the RS based on MAC addresses. All packets received by a port are dropped. When combined with static entries, however, these filters can be used to drop all received traffic but allow some frames to go through.

25.2.1 Configuring Layer-2 Address Filters

If you want to control access to a source or destination on a per-MAC address basis, you can configure an address filter. Address filters are always configured and applied to the input port. You can set address filters on the following:

- A source MAC address, which filters out any frame coming from a specific source MAC address
- A destination MAC address, which filters out any frame destined to specific destination MAC address
- A flow, which filters out any frame coming from a specific source MAC address that is also destined to a specific destination MAC address

To configure Layer-2 address filters, enter the following commands in Configure mode:

Configure a source MAC based address filter.	**filters add address-filter name** *<name>* **source-mac** *<MACaddr>***|any source-mac-mask** *<mask>***|any vlan** *<VLAN-num>***|any in-port-list** *<port-list>*
Configure a destination MAC based address filter.	**filters add address-filter name** *<name>* **dest-mac** *<MACaddr>***|any dest-mac-mask** *<mask>* **vlan** *<VLAN-num>***|any in-port-list** *<port-list>*
Configure a Layer-2 flow address filter.	**filters add address-filter name** *<name>* **source-mac** *<MACaddr>***|any source-mac-mask** *<mask>* **dest-mac** *<MACaddr>***|any dest-mac-mask** *<mask>* **vlan** *<VLAN-num>***|any in-port-list** *<port-list>*

25.2.2 Configuring Layer-2 Port-to-Address Lock Filters

Port address lock filters allow you to bind or "lock" specific source MAC addresses to a port or set of ports. Once a port is locked, only the specified source MAC address is allowed to connect to the locked port and the specified source MAC address is not allowed to connect to any other ports.

To configure Layer-2 port address lock filters, enter the following commands in Configure mode:

Configure a port address lock filter.	**filters add port-address-lock name** *<name>* **source-mac** *<MACaddr>* **vlan** *<VLAN-num>* **in-port-list** *<port-list>*

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25.2.3 Configuring Layer-2 Static Entry Filters

Static entry filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port. You can set the following static entry filters:

- Source static entry, which specifies that any frame coming from source MAC address will be allowed or disallowed, or forced to go to a set of ports
- Destination static entry, which specifies that any frame destined to a specific destination MAC address will be allowed, disallowed, or forced to go to a set of ports
- Flow static entry, which specifies that any frame coming from a specific source MAC address that is destined to specific destination MAC address will be allowed, disallowed, or forced to go to a set of ports

To configure Layer-2 static entry filters, enter the following commands in Configure mode:

Configure a source static entry filter.	**filters add static-entry name** *<name>* **restriction allow|disallow|force source-mac** *<MACaddr>***|any source-mac-mask** *<mask>* **vlan** *<VLAN-num>***|any in-port-list** *<port-list>* **out-port-list** *<port-list>*
Configure a destination static entry filter.	**filters add static-entry name** *<name>* **restriction allow|disallow|force dest-mac** *<MACaddr>* **dest-mac-mask** *<mask>***|any vlan** *<VLAN-num>***|any in-port-list** *<port-list>* **out-port-list** *<port-list>*

25.2.4 Configuring Layer-2 Secure Port Filters

Secure port filters block access to a specified port. You can use a secure port filter by itself to secure unused ports. Secure port filters can be configured as source or destination port filters. A secure port filter applied to a source port forces all incoming packets to be dropped on a port. A secure port filter applied to a destination port prevents packets from going out a certain port.

You can combine secure port filters with static entries in the following ways:

- Combine a source secure port filter with a source static entry to drop all received traffic but allow any frame coming from specific source MAC address to go through.
- Combine a source secure port filter with a flow static entry to drop all received traffic but allow any frame coming from a specific source MAC address that is destined to specific destination MAC address to go through.
- Combine a destination secure port with a destination static entry to drop all received traffic but allow any frame destined to specific destination MAC address go through.
- Combine a destination secure port filter with a flow static entry to drop all received traffic but allow any frame coming from specific source MAC address that is destined to specific destination MAC address to go through.

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To configure Layer-2 secure port filters, enter the following commands in Configure mode:

Configure a source secure port filter.	**filters add secure-port name** *<name>* **direction source vlan** *<VLAN-num>* **in-port-list** *<port-list>*
Configure a destination secure port filter.	**filters add secure-port name** *<name>* **direction destination vlan** *<VLAN-num>* **in-port-list** *<port-list>*

25.2.5 Monitoring Layer-2 Security Filters

The RS provides display of Layer-2 security filter configurations contained in the routing table.

To display security filter information, enter the following commands in Enable mode.

Show address filters.	**filters show address-filter [all-source|all-destination|all-flow] [source-mac** *<MACaddr>* **dest-mac** *<MACaddr>***] [ports** *<port-list>***] [vlan** *<VLAN-num>***]**
Show port address lock filters.	**filters show port-address-lock ports [ports** *<port-list>***] [vlan** *<VLAN-num>***] [source-mac** *<MACaddr>***]**
Show secure port filters.	**filters show secure-port**
Show static entry filters.	**filters show static-entry [all-source|all-destination|all-flow] ports** *<port-list>* **vlan** *<VLAN-num>* **[source-mac** *<MACaddr>* **dest-mac** *<MACaddr>***]**

25.2.6 Layer-2 Filter Examples

Figure 25-1shows the router connections for which layer-2 security filters will be configured.

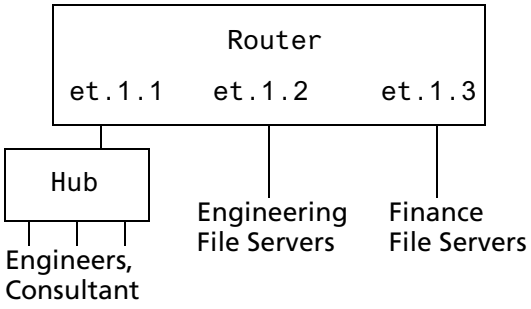

Figure 25-1 Source filter example

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Example 1: Address Filters

Source filter: The consultant is not allowed to access any file servers. The consultant is only allowed to interact with the engineers on the same Ethernet segment – port et.1.1. All traffic coming from the consultant's MAC address will be dropped.

```
filters add address-filter name consultant source-mac 001122:334455 vlan 1
    in-port-list et.1.1
```

Destination filter: No one from the engineering group (port et.1.1) should be allowed to access the finance server. All traffic destined to the finance server's MAC will be dropped.

```
filters add address-filter name finance dest-mac AABBCC:DDEEFF vlan 1 in-port-list
    et.1.1
```

Flow filter: Only the consultant is restricted access to one of the finance file servers. Note that port et.1.1 should be operating in flow-bridging mode for this filter to work.

```
filters add address-filter name consult-to-finance source-mac 001122:334455 dest-mac
    AABBCC:DDEEFF vlan 1 in-port-list et.1.1
```

Static Entries Example

Source static entry: The consultant is only allowed to access the engineering file servers on port et.1.2.

```
filters add static-entry name consultant source-mac 001122:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Destination static entry: Restrict "login multicasts" originating from the engineering segment (port et.1.1) from reaching the finance servers.

```
filters add static-entry name login-mcasts dest-mac 010000:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.3 restriction disallow
```


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or

```
filters add static-entry name login-mcasts dest-mac 010000:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Flow static entry: Restrict "login multicasts" originating from the consultant from reaching the finance servers.

```
filters add static-entry name consult-to-mcasts source-mac 001122:334455  dest-mac
    010000:334455 vlan 1 in-port-list et.1.1 out-port-list et.1.3 restriction disallow
```

Port-to-Address Lock Examples

You have configured some filters for the consultant on port et.1.1 If the consultant plugs his laptop into a different port, he will bypass the filters. To lock him to port et.1.1, use the following command:

```
filters add port-address-lock name consultant source-mac 001122:334455 vlan 1
    in-port-list et.1.1
```

Note If the consultant's MAC is detected on a different port, all of its traffic will be blocked.

Example 2 : Secure Ports

Source secure port: To block all engineers on port 1 from accessing all other ports, enter the following command:

```
filters add secure-port name engineers direction source vlan 1
    in-port-list et.1.1
```


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To allow ONLY the engineering manager access to the engineering servers, you must "punch" a hole through the secure-port wall. A "source static-entry" overrides a "source secure port".

```
filters add static-entry name eng-mgr source-mac 080060:123456 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Destination secure port: To block access to all file servers on all ports from port et.1.1 use the following command:

```
filters add secure-port name engineers direction dest vlan 1
    in-port-list et.1.1
```

To allow all engineers access to the engineering servers, you must "punch" a hole through the secure-port wall. A "dest static-entry" overrides a "dest secure port".

```
filters add static-entry name eng-server dest-mac 080060:abcdef vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

25.3 LAYER-3 ACCESS CONTROL LISTS (ACLS)

Access Control Lists (ACLs) allow you to restrict Layer-3/4 traffic going through the RS. Each ACL consists of one or more rules describing a particular type of IP or IPX traffic. An ACL can be simple, consisting of only one rule, or complicated with many rules. Each rule tells the router to either permit or deny the packet that matches the rule's packet description.

For information about defining and using ACLs on the RS, see Chapter 24, *"Access Control List Configuration."*

25.4 LAYER-4 BRIDGING AND FILTERING

Layer-4 bridging is the RS's ability to use layer-3/4 information to perform filtering or QoS during bridging. As described in Section 25.2, *"Layer-2 Security Filters,"* above, you can configure ports to filter traffic using MAC addresses. Layer-4 bridging adds the ability to use IP addresses, layer-4 protocol type, and port number to filter traffic in a bridged network. Layer-4 bridging allows you to apply security filters on a "flat" network, where the client and server may reside on the same subnet.

Note Ports that are included in a layer-4 bridging VLAN must reside on updated RS hardware.

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To illustrate this, the following diagram shows an RS serving as a bridge for a consultant host, file server, and an engineering host, all of which reside on a single subnet.

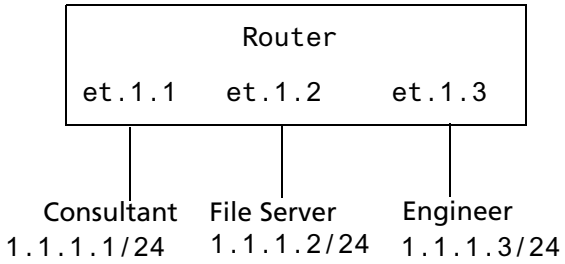

Figure 25-2 Sample VLAN for layer-4 bridging

You may want to allow the consultant access to the file server for e-mail (SMTP) traffic, but not for Web (HTTP) traffic and allow e-mail, Web, and FTP traffic between the engineer and the file server. You can use Layer-4 bridging to set this up.

Setting up Layer-4 bridging consists of the following steps:

- Creating an IP or IPX VLAN
- Placing the ports on the same VLAN
- Enabling Layer-4 Bridging on the VLAN
- Creating an ACL that specifies the selection criteria
- Applying an ACL to a port

25.4.1 Creating an IP or IPX VLAN for Layer-4 Bridging

To enable Layer-4 bridging on a VLAN, the VLAN must be configured to pass only IP or only IPX traffic. (Therefore, you cannot enable Layer-4 bridging on port-based VLANS.) To create an IP or IPX VLAN, enter the following command in Configure mode:

Create an IP or IPX VLAN.	**vlan create** <*vlan-name*> <*type*> **id** <*num*>

For example, to create an IP VLAN called “blue” with an ID of 21, enter the following command in Configure mode:

```
rs(config)# vlan create blue ip id 21
```


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25.4.2 Placing the Ports on the Same VLAN

Once you have created a VLAN for the ports to be used in layer-4 bridging, you add those ports to the VLAN. To add ports to a VLAN, enter the following command in Configure mode:

Add ports to a VLAN.	**vlan add ports** <*port-list*> **to** <*vlan-name*>

To add the ports in the example in Figure 25-2, to the blue VLAN you would enter the following command:

```
rs(config)# vlan add ports et.1.1,et.1.2,et.1.3 to blue
```

25.4.3 Enabling Layer-4 Bridging on the VLAN

After adding the ports to the VLAN, you enable Layer-4 Bridging on the VLAN. To do this, enter the following command in Configure mode:.

Enable Layer 4 bridging.	**vlan enable l4-bridging on** <*vlan-name*>

For example, to enable Layer-4 Bridging on the blue VLAN:

```
rs(config)# vlan enable l4-bridging on blue
```

25.4.4 Creating ACLs to Specify Selection Criteria for Layer-4 Bridging

Access control lists (ACLs) specify the kind of filtering to be done for Layer-4 Bridging.

In the example in Figure 25-2, to allow the consultants access to the file server for e-mail (SMTP) traffic, but not for Web (HTTP) traffic — and allow e-mail, Web, and FTP traffic between the engineers and the file server, you would create ACLs that allow only SMTP traffic on the port to which the consultants are connected and allow SMTP, HTTP, and FTP traffic on the ports to which the engineers are connected.

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The following is an example:

```
acl 100 permit ip any any smtp
acl 100 deny ip any any http

acl 200 permit any any smtp
acl 200 permit any any http
acl 200 permit any any ftp
```

ACL 100 explicitly permits SMTP traffic and denies HTTP traffic. Note that because of the implicit deny rule appended to the end of the ACL, all traffic (not just HTTP traffic) other than SMTP is denied.

ACL 200 explicitly permits SMTP, HTTP, and FTP traffic. The implicit deny rule denies any other traffic. See Section 24.2, *"Creating and Modifying ACLs,"* for more information on defining ACLs.

25.4.5 Applying a Layer-4 Bridging ACL to a Port

Finally, you apply the ACLs to the ports in the VLAN. To do this, enter the following command in Configure mode:

Apply a Layer-4 bridging ACL to a port	**acl** *<name>* **apply port** *<port-list>*

For the example in Figure 25-2, to apply ACL 100 (which denies all traffic except SMTP) to the consultant port:

```
rs(config)# acl 100 apply port et.1.1 output
```

To apply ACL 200 (which denies all traffic except SMTP, HTTP, and FTP) to the engineer port:

```
rs(config)# acl 200 apply port et.1.3 output
```

25.4.6 Notes

- Layer-4 Bridging works for IP and IPX traffic only. The RS will drop non-IP/IPX traffic on a Layer-4 Bridging VLAN. For Appletalk and DECnet packets, a warning is issued before the first packet is dropped.

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- If you use a SmartTRUNK in a with Layer-4 Bridging VLAN, the RS maintains the packet order on a per-flow basis, rather than per-MAC pair. This means that for traffic between a MAC pair consisting of more than one flow, the packets may be disordered if they go through a SmartTRUNK. For traffic that doesn't go through a SmartTRUNK, the per-MAC pair packet order is kept.
- ACLs applied to a network interface (as opposed to a port) do not have an effect on Layer-4 Bridged traffic, even though the interface may include ports used in Layer-4 Bridging.

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26 QOS CONFIGURATION

The RS allows network managers to identify traffic and set Quality of Service (QoS) policies without compromising wire speed performance. The RS can guarantee bandwidth on an application by application basis, thus accommodating high-priority traffic even during peak periods of usage. QoS policies can be broad enough to encompass all the applications in the network, or relate specifically to a single host-to-host application flow.

The RS provides four different features to satisfy QoS requirements:

Traffic Prioritization – Allows network administrators to differentiate between mission-critical network traffic and non-critical network traffic and segregate the traffic into different priority queues . Once a packet has been identified, it can be assigned to any one of the four priority queues in order to ensure delivery. Priority can be allocated based on any combination of Layer-2, Layer-3, or Layer-4 traffic.

Weighted Random Early Detection (WRED) – Alleviates traffic congestion by randomly dropping packets before the queues pass their upper thresholds. WRED is intended to work with connection-oriented protocols (especially TCP). However, WRED when applied to a port receiving connectionless traffic can reduce latency on that port.

Type of Service (ToS) – ToS Rewrite provides network administrators access to the ToS octet in an IP packet. The ToS octet is designed to provide feedback to the upper layer application. The administrator can mark packets using the ToS rewrite feature so that the application (a routing protocol, for example) can handle the packet based on a predefined mechanism.

Traffic Rate Limiting – Provides network administrators with tools to manage bandwidth resources. The administrator can create an upper limit for a traffic profile, which is based on Layer-3 or Layer-4 information. Traffic that exceeds the upper limit of the profile can either be dropped or re-prioritized into another priority queue.

Within the RS, QoS policies are used to classify Layer-2, Layer-3, and Layer-4 traffic into the following priority queues (in order from highest priority to lowest):

- Control
- High
- Medium
- Low

Note Control is for router control traffic. The remaining classes are for normal data flows.

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Separate buffer space is allocated to each of these four priority queues. By default, buffered traffic in higher priority queues is forwarded ahead of pending traffic in lower priority queues. This is the *strict priority* queuing policy. During heavy loads, low-priority traffic can be dropped to preserve the throughput of the higher-priority traffic. This ensures that critical traffic will reach its destination even if the exit ports for the traffic are experiencing greater-than-maximum utilization. To prevent low-priority traffic from waiting indefinitely as higher-priority traffic is sent, you can apply the Weighted Fair Queuing (WFQ) queuing policy to set a minimum bandwidth for each class. You can also apply WRED to keep the congestion of TCP traffic under control.

26.1 LAYER-2, LAYER-3 AND LAYER-4 FLOW SPECIFICATION

In the RS, traffic classification is accomplished by mapping Layer-2, -3, or -4 traffic to one of the four priorities. Each traffic classification is treated as an individual traffic flow in the RS.

For Layer-2 traffic, you can define a flow based on MAC packet header fields, including source MAC address, destination MAC address, and VLAN IDs. A list of incoming ports can also be specified.

For Layer-3 (IP and IPX) traffic, you can define flows, blueprints or templates of IP and IPX packet headers:

Ip Fields – The source IP address, destination IP address, UDP/TCP source port, UDP/TCP destination port, TOS (Type of Service), transport protocol (TCP or UDP), and a list of incoming interfaces.

Ipx Fields – The source network, source node, destination network, destination node, source port, destination port, and a list of incoming interfaces.

For Layer-4 traffic, you can define a flow based on source/destination TCP/UDP port number in addition to the Layer-3 source/destination IP address.

The flows specify the contents of these fields. If you do not enter a value for a field, a wildcard value (all values acceptable) is assumed for the field.

26.2 PRECEDENCE FOR LAYER-3 FLOWS

A precedence from 1 to 7 is associated with each field in a flow. The RS uses the precedence value associated with the fields to break ties if packets match more than one flow. The highest precedence is 1 and the lowest is 7. Here is the default precedence of the fields:

- IP
  - Destination port – 1
  - Destination IP address – 2
  - Source port – 3
  - Source IP address – 4
  - ToS – 5
  - Interface – 6
  - Protocol – 7

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- IPX
  - Destination network – 1
  - Source network – 2
  - Destination node – 3
  - Source node – 4
  - Destination port – 5
  - Source port – 6
  - Interface – 7

Use the **`qos precedence ip`** and **`qos precedence ipx`** commands to change the default precedence.

26.3 RS QUEUING POLICIES

There are two types of queuing policies you can use on the RS:

Strict priority – Assures the higher priorities of throughput but at the expense of lower priorities. For example, during heavy loads, low-priority traffic can be dropped to preserve throughput of control-priority traffic. This is the default queuing policy.

Weighted fair queuing – Distributes priority throughput among the four priorities based on percentages. This queuing policy is set on a per-port basis.

26.4 TRAFFIC PRIORITIZATION FOR LAYER-2 FLOWS

QoS policies applied to Layer-2 flows allow you to assign priorities based on source and destination MAC addresses. A QoS policy set for a Layer-2 flow allows you to classify the priority of traffic from:

- A specific source MAC address to a specific destination MAC address (use only when the port is in flow bridging mode).
- Any source MAC address to a specific destination MAC address.

Before applying a QoS policy to a Layer-2 flow, you must first determine whether a port is in the address-bridging mode or flow-bridging mode. If a port is operating in address-bridging mode (default), you can specify the priority based on the destination MAC address and a VLAN ID. You can also specify a list of ports to apply the policy.

If a port is operating in the flow-bridging mode, you can be more specific and configure priorities for frames that match both a source and a destination MAC address and a VLAN ID. You can also specify a list of ports to apply the policy.

The VLAN ID in the QoS configuration must match the VLAN ID assigned to the list of ports to which the QoS policy is applied. In a Layer-2 only configuration, each port has only one VLAN ID associated with it and the QoS policy should have the same VLAN ID. When different VLANs are assigned to the same port using different protocol VLANs, the Layer-2 QoS policy must match the VLAN ID of the protocol VLAN.

Note In the flow mode, you can also ignore the source MAC address and configure the priority based on the destination MAC address only.

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26.4.1 Configuring Layer-2 QoS

When applying QoS to a layer-2 flow, priority can be assigned as follows:

- The frame gets assigned a priority within the switch. Select low, medium, high or control.
- The frame gets assigned a priority within the switch, and if the exit ports are VLAN trunk ports, the frame is assigned an 802.1p priority. Select a number from 0 to 7.

To set a QoS priority on a layer-2 flow, enter the following command in the Configure mode:

Set a layer-2 QoS policy.	**qos set l2 name** *<name>* **source-mac** *<MACaddr>* **| any source-mac-mask** *<MACaddr>* **dest-mac** *<MACaddr>* **| any dest-mac-mask** *<MACadddr>* **vlan** *<vlanID>* **| any in-port-list** *<port-list>* **priority control | high | medium | low** | *<trunk-priority>*

26.4.2 802.1p Class of Service Priority Mapping

The following table shows the default mappings of 802.1p Class of Service (CoS) values to internal priorities for frames:

Table 26-1 802.1p default priority mappings

802.1p CoS values	Internal priority queue
0, 1	Low
2, 3	Medium
4, 5	High
6, 7	Control

You can create one or more priority maps that are different from the default priority map and then apply these maps to some or all ports on the RS. The new priority mapping replaces the default mappings for those ports.

Creating and Applying a New Priority Map

To specify a priority map on a per-port basis, enter the following commands in the Configure mode:

Create a new priority mapping.	**qos create priority-map** *<name>* *<CoS number>* **control | high | medium | low**
Apply new priority mapping to ports.	**qos apply priority-map** *<name>* **ports** *<port-list>*

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For example, the following command creates the priority map *all-low* which maps all 802.1p priorities to the low internal priority queue:

```
qos create priority-map all-low 0 low 1 low 2 low 3 low 4 low 5 low 6 low 7 low
```

Once a priority map is created, it can then be applied to a set of ports, as shown in the following example:

```
qos apply priority-map all-low ports et.1.1-4, gi.4.*
```

In the above example, ports et.1.1-4 and ports gi.4.* will use the *all-low* priority map. All other ports, including ports et.1.5-8, will use the default priority map.

You do not need to specify mappings for all 802.1p values. If you do not specify a particular mapping, the default mapping for that 802.1p priority is used. The following example creates a priority map *no-ctrl* with the same mappings as the default priority map, except that the 802.1p priority of 7 is mapped to the internal priority high instead of control.

```
qos create priority-map no-ctrl 7 high
```

Removing or Disabling Per-Port Priority Map

Negating a **qos create priority-map** command removes the priority map. Before you can remove a priority map, you must negate all commands that use the priority map. Negating a **qos apply priority-map** command causes the configured ports to use the default priority mapping.

The ability to specify per-port priority maps is enabled on the RS by default. You can disable use of per-port priority maps on the RS. All ports on the RS will then be configured to use the default priority map only. If the commands to create and apply priority maps exist in the active configuration, they will remain in the configuration but be ineffective.

To disable the use of priority maps, enter the following command in the Configure mode:

Disable use of per-port priority maps on the RS.	**qos priority-map off**

If the above command is negated, ports on the RS can use per-port priority maps. If the commands to create and apply priority maps exist in the active configuration, they are reapplied.

Displaying Priority Map Information

To display priority maps and the ports on which they are applied, enter the following command in Enable mode:

Display priority mapping.	**qos show priority-map** *<name>* **| all**

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26.5 TRAFFIC PRIORITIZATION FOR LAYER-3 & LAYER-4 FLOWS

QoS policies applied at Layer-3 and -4 allow you to assign priorities based on specific fields in the IP and IPX headers. You can set QoS policies for IP flows based on source IP address, destination IP address, source TCP/UDP port, destination TCP/UDP port, type of service (TOS) and transport protocol (TCP or UCP). You can set QoS policies for IPX flows based on source network, source node, destination network, destination node, source port and destination port. A QoS policy set on an IP or IPX flow allows you to classify the priority of traffic based on:

- Layer-3 source-destination flows
- Layer-4 source-destination flows
- Layer-4 application flows

26.5.1 Configuring IP QoS Policies

To configure an IP QoS policy, perform the following tasks:

1. Identify the Layer-3 or -4 flow and set the IP QoS policy.
2. Specify the precedence for the fields within an IP flow.

Setting an IP QoS Policy

To set a QoS policy on an IP traffic flow, use the following command in the Configure mode:

Set an IP QoS policy.	**qos set ip** *<name> <priority> <srcaddr/mask>* **| any** *<dstaddr/mask>* **| any** *<srcport>* **| any** *<dstport>* **| any** *<tos>* **| any** *<port list>* | <interface-list> **| any** *<protocol>* **| any** *<tos-mask>* **| any** *<tos-precedence-rewrite>* **| any** *<tos-rewrite>* **| any**

For example, the following command assigns control priority to any traffic coming from the 10.10.11.0 network:

```
qos set ip xyz control 10.10.11.0/24
```

Specifying Precedence for an IP QoS Policy

To specify the precedence for an IP QoS policy, use the following command in the Configure mode:

Specify precedence for an IP QoS policy.	**qos precedence ip** [**sip** *<num>*] [**dip** *<num>*] [**srcport** *<num>*] [**destport** *<num>*] [**tos** *<num>*] [**protocol** *<num>*] [**intf** *<num>*]

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26.5.2 Configuring IPX QoS Policies

To configure an IPX QoS policy, perform the following tasks:

1. Identify the Layer-3 or 4 flow, and set the IPX QoS policy.
2. Specify the precedence for the fields within an IPX flow.

Setting an IPX QoS Policy

To set a QoS policy on an IPX traffic flow, enter the following command in Configure mode:

Set an IPX QoS policy.	**qos set ipx** *<name> <priority> <srcnet>* **| any** *<srcmask>* **| any** *<srcport>* **| any** *<dstnet>* **| any** *<dstmask>* **| any** *<dstport>* **| any** *<port list>* | *<interface-list>* **| any**

Specifying Precedence for an IPX QoS Policy

To specify the precedence for an IPX QoS policy, enter the following command in the Configure mode:

Specify precedence for an IPX QoS policy.	**qos precedence ipx** [**srcnet** *<num>*] [**srcnode** *<num>*] [**srcport** *<num>*] [**dstnet** *<num>*] [**dstnode** *<num>*] [**dstport** *<num>*] [**intf** *<num>*]

26.6 CONFIGURING RS QUEUEING POLICY

The RS default queuing policy, strict priority, is set on a system-wide basis. To change the queuing policy for a specific port or ports to weighted-fair queuing, enter the following command in the Configure mode:

Set queuing policy to weighted-fair.	**qos set queuing-policy weighted-fair port** *<port list>* **| all-ports**

If you want to revert the RS queuing policy from weighted-fair to strict priority (default), enter the following command in the Configure mode:

Revert the RS queuing policy to strict priority.	**negate** *<line within active-configuration containing qos set queuing-policy weighted-fair>*

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26.6.1 Allocating Bandwidth for a Weighted-Fair Queuing Policy

If you enable the weighted-fair queuing policy on the RS, you can allocate bandwidth for the queues on the RS. To allocate bandwidth for each queue, enter the following command in the Configure mode:

Allocate bandwidth for a weighted-fair queuing policy.	**qos set weighted-fair control** *<percentage>* **high** *<percentage>* **medium** *<percentage>* **low** *<percentage>* **port** *<port list>* **| all-ports**

26.7 WEIGHTED RANDOM EARLY DETECTION (WRED)

WRED is a dynamic process for controlling congestion on RS ports and the segments of the network associated with the WRED enabled ports. The WRED process consists of setting a *minimum queue threshold* (min-threshold) and a *maximum queue threshold* (max-threshold) on any of the four queues (low, medium, high, and control) belonging to a port. Associated with these thresholds is an *average queue size*, which is dynamically calculated as the instantaneous average buffer depth. If the average queue size is below the min-threshold, no packets are discarded. However, if the average queue size rises above the min-threshold, WRED uses a *packet-marking probability* algorithm to randomly mark packets for discard. As the average queue size increases toward the max-threshold, the probability of packet drop also increases. Eventually, if the average queue size exceeds the max-threshold, the probability of packet drop becomes 1 (100% of packets are dropped). This increase in the probability of packet drop increases in a linear fashion from 0 to 1 (0% dropped to 100% dropped). Notice that the probability of packet drop roughly depends on bandwidth, i.e.; the more packets sent by a particular connection, the greater the probability that packets will be dropped from that connection.

26.7.1 WRED's Effect on the Network

WRED's full capabilities to reduce congestion are best used with TCP (and other connection-oriented protocols). As TCP traffic increases on a WRED port, and the average queue size rises above the min-threshold, some TCP packets begin to drop. Each TCP source interprets dropped packets as an indication of congestion. As a result, each TCP source that has experienced a dropped packet reduces its window, the average queue size decreases, and congestion is alleviated.

Although connection-less protocols do not have the response capability of TCP to sense congestion. Nevertheless, WRED's technique of dropping packets based on rising probability assures that those connections that are sending the most packets or using the most bandwidth will be more likely to have their packets dropped than lower bandwidth connections. This provides at least some assurance of equality of throughput on a WRED port for connection-less protocols.

26.7.2 Weighting Algorithms in WRED

WRED provides for the "fine-tuning" of both the average queue size algorithm and the packet-marking probability algorithm. Control over the average queue size algorithm is provided by the **exponential-weighting-constant** parameter, while control over the packet-marking probability algorithm is provided by the **mark-prob-denominator** parameter.

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The **exponential-weighting-constant** parameter specifies how fast the average queue size changes in response to changes in the actual queue depth. In effect, the rate of change of the average queue size can be dampened. The **exponential-weighting-constant** accepts values from zero (0) to three (3) when WRED is applied to input queues, and from zero (0) to seven (7) when WRED is applied to output queues. Note that 0 provides the least amount of dampening, while larger numbers provide greater amounts of dampening.

This ability to dampen the response time of the average queue size changes WRED's response to bursty traffic. For example, notice in Figure 26-1 that while the traffic (solid line) bursts at times, the average queue size (dotted curve) is dampened such that it does not rise above the minimum threshold within the duration of the bursts. This keeps the port from discriminating against traffic that might burst slightly at times.

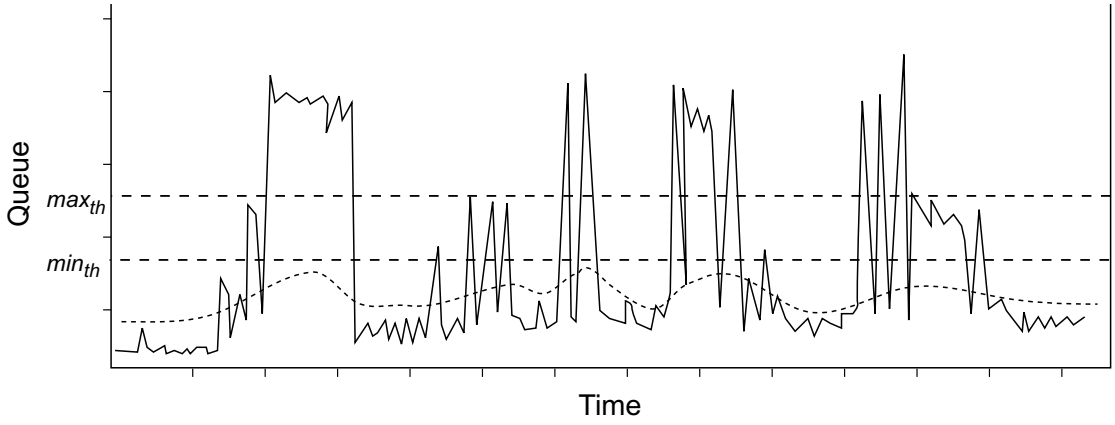

Figure 26-1 Average queue size and bursty traffic

The **mark-prob-denominator** parameter is used to determine the probability of a packet being dropped when the average queue size is between the minimum and maximum thresholds. The **mark-prob-denominator** accepts values from zero (0) to three (3) when WRED is applied to input queues and from zero (0) to seven (7) when WRED is applied to output queues. Note that the lower the value specified, the higher the probability that packets will be dropped.

Both the **exponential-weighting-constant** value and the **mark-prob-denominator** value are somewhat allegorical in the sense that neither of these values have a direct numerical significance other than acting as control values for WRED. For example, if the value for **exponential-weighting-constant** is increased from 1 to 2, the dampening of the average queue size response is not twice as slow. Because of this non-specific nature of **exponential-weighting-constant** and **mark-prob-denominator** and the fact that each network is different, a discussion of recommend, specific settings for these values is beyond the scope of this User Guide.

When first implementing WRED on your RS, it is recommended to initially use the default values for min-threshold, max-threshold, the weighting constant, and the probability denominator. If you begin or continue to experience congestion, especially with TCP traffic, try adjusting WRED by making small changes in the various parameters (one-at-a-time), and observing their effect on congestion.

To enable WRED on queues of specific input or output ports, enter the following command in Configure mode:

Enable WRED on input or output queue of specified ports.	**qos wred input|output** [**exponential-weighting-constant** <*num*>] [**mark-prob-denominator** <*num*>] [**max-queue-threshold** <*num*>] [**min-queue-threshold** <*num*>] [**port** <port list> **| all-ports**] [**queue control | high | medium | low**]

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26.8 TOS REWRITE

IP packets that use different paths are subject to delays, as there is little inherent knowledge of how to optimize the paths for different packets from different applications or users. The IP protocol actually provides a facility, which has been part of the IP specification since the protocol's inception, for an application or upper-layer protocol to specify how a packet should be handled. This facility is called the Type of Service (ToS) octet.

The ToS octet part of the IP specification, however, has not been widely employed in the past. The IETF is looking into using the ToS octet to help resolve IP quality problems. Some newer routing protocols, like OSPF and IS-IS, are designed to be able to examine the ToS octet and calculate routes based on the type of service.

The ToS octet in the IP datagram header consists of three fields:

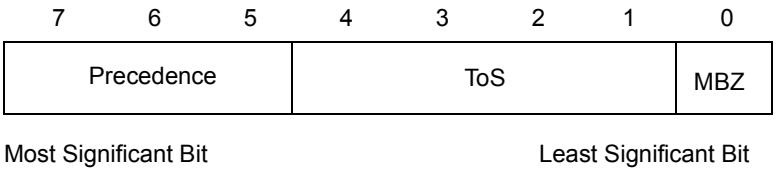

Figure 26-2 ToS fields

- The three-bit Precedence field is used to indicate the priority of the datagram.
- The four-bit ToS field is used to indicate trade-offs between throughput, delay, reliability, and cost.
- The one-bit "must be zero" (MBZ) field is not currently used. (In the RS configuration, there is no restriction on this bit and it is included as part of the ToS field.)

For example, setting the ToS field to 0010 specifies that a packet will be routed on the most reliable paths. Setting the ToS field to 1000 specifies that a packet will be routed on the paths with the least delay. (Refer to RFC 1349 for the specification of the ToS field value.)

With the ToS rewrite command, you can access the value in the ToS octet (which includes both the Precedence and ToS fields) in each packet. The upper-layer application can then decide how to handle the packet, based on either the Precedence or the ToS field or both fields. For example, you can configure a router to forward packets using different paths, based on the ToS octet. You can also change the path for specific applications and users by changing the Precedence and/or ToS fields.

Note In RFC 2574, the IETF redefined the ToS octet as the *DiffServ* byte. You will still be able to use the ToS rewrite feature to implement *DiffServ* when this standard is deployed.

26.8.1 Configuring ToS Rewrite for IP Packets

The ToS rewrite for IP packets is set with the **`qos set`** command in the Configure mode. You can define the QoS policy based on any of the following IP fields:

- Source IP address
- Destination IP address

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- Source port
- Destination port
- ToS
- Port
- Interface

When an IP packet is received, the ToS field of the packet is ANDed with the <*tos-mask*> and the resulting value is compared with the ANDed value of <*tos*> and <*tos-mask*> of the QoS policy. If the values are equal, the values of the <*tos-rewrite*> and <*tos-precedence-rewrite*> parameters will be written into the packet.

The <*tos*> and <*tos-mask*> parameters use values ranging from 0 to 255. They are used in conjunction with each other to define which bit in the <*tos*> field of the packet is significant. The <*tos-precedence-rewrite*> value ranges from 0 to 7 and is the value that is rewritten in the ToS Precedence field (the first three bits of the ToS octet). The <*tos-rewrite*> value ranges from 0 to 31 and is the value that is rewritten in the ToS field.

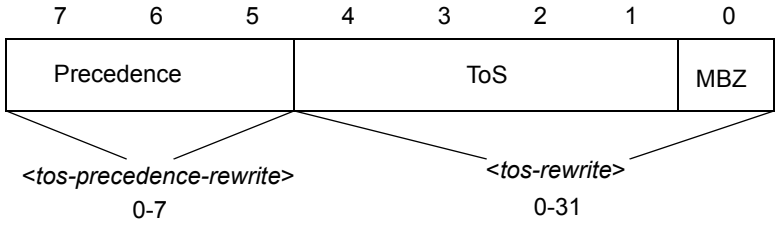

Figure 26-3 ToS rewrite

The ToS byte rewrite is part of the QoS priority classifier group. The entire ToS byte can be rewritten or only the precedence part of the ToS byte can be rewritten. If you specify a value for <*tos-precedence-rewrite*>, then only the upper three bits of the ToS byte are changed. If you set <*tos-precedence-rewrite*> to **any** and specify a value for <*tos-rewrite*>, then the upper three bits remain unchanged and the lower five bits are rewritten. If you specify values for both <*tos-precedence-rewrite*> and <*tos-rewrite*>, then the upper three bits are rewritten to the <*tos-precedence-rewrite*> value and the lower five bits are rewritten to the <*tos-rewrite*> value.

For example, the following command will rewrite the ToS Precedence field to 7 if the ToS Precedence field of the incoming packet is 6:

```
qos set ip tosp6to7 low any any any any 222 any any 224 7
```

In the above example, the <*tos*> value of 222 (binary value 1101 1110) and the <*tos-mask*> value of 224 (binary value 1110 0000) are ANDed together to specify the ToS Precedence field value of 6 (binary value 110). Changing the value in the <*tos-mask*> parameter determines the bit in the ToS octet field that will be examined.

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The following example will rewrite the ToS Precedence and the ToS fields to 5 and 30 if the incoming packet is from the 10.10.10.0/24 network with the ToS Precedence field set to 2 and the ToS field set to 7. In this example, the MBZ bit is included in the ToS field. The figure below shows how the parameter values are derived.

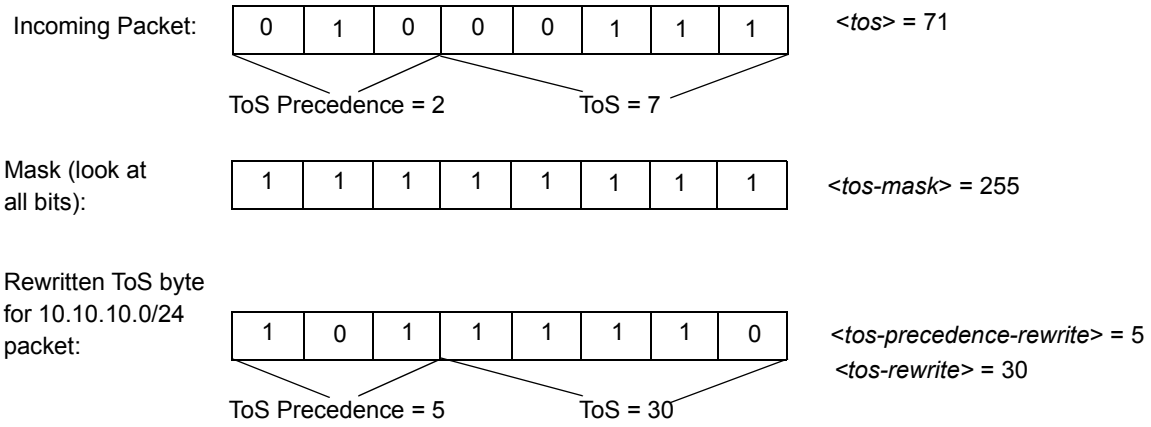

Figure 26-4 ToS rewrite example

The *<tos-mask>* value determines the ToS bit to be examined, which is all eight bits in this example. The following command configures the ToS rewrite for the example:

```
qos set ip tos30to7 low 10.10.10.0/24 any any any 71 any any 255 5 30
```

26.9 MONITORING QOS

The RS provides display of QoS statistics and configurations contained in the RS.

To display QoS information, enter the following commands in Enable mode:

Show all IP QoS flows.	**qos show ip**
Show all IPX QoS flows.	**qos show ipx**
Show all Layer-2 QoS flows.	**qos show l2 all-destination all-flow ports** *<port-list>* **vlan** *<vlanID>* **source-mac** *<MACaddr>* **dest-mac** *<MACaddr>*
Show RED parameters for each port.	**qos show red** [**input port** *<port-list>* **| all-ports**] [**output port** *<port-list>* **| all-ports**] [**port** *<port-list>* **| all-ports**]
Show IP or IPX precedence values.	**qos show precedence ip | ipx**
Show WFQ bandwidth allocated for each port.	**qos show wfq** [**port** *<port-list>* **| all-ports**] [**input** *<slot num>*] **| all-modules**]
Show priority mappings.	**qos show priority-map all**

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26.10 LIMITING TRAFFIC RATE

Note Some commands in this facility require updated RS hardware.

Rate limiting provides the ability to control the usage of a fundamental network resource, bandwidth. It allows you to limit the rate of traffic that flows through the specified interfaces, thus reserving bandwidth for critical applications. The RS supports the following types of rate limiting:

Per-flow Rate Limiting – Configure policies that limit individual flows to a specified rate. This is the default rate limiting mode on the RS.

Aggregate Rate Limiting – Configure policies that limit an aggregation of flows (all flows that match an ACL) to a specified rate. This type of rate limiting is performed completely in hardware and must be enabled on a per-line card basis. If you enable aggregate rate limiting on a line card, you cannot use per-flow or flow-aggregate rate limiting with that card.

Note Aggregate rate limiting is only supported on certain line cards. Make sure the line card supports hardware rate limiting.

- **Software-based Flow-aggregate Rate Limiting** – Configure policies that limit an aggregation of flows (all flows that match an ACL) to a specified rate. For example, limit traffic to or from a particular subnet. This type of rate limiting is performed mostly in software. However, forwarding of packets is done in the hardware. Flow-aggregate rate limiting is designed for use with line cards that do not support aggregate rate limiting.
- **Port-level Rate Limiting** – Configure policies that limit traffic coming into a particular port. This type of policy can be used to limit any type of traffic and is enabled on a per line card basis. If you enable port-level rate limiting on a line card, you cannot use per-flow or flow-aggregate rate limiting with that card.

Note You can also limit outbound traffic by using the WAN rate shaping feature described in Section 30.13, *"WAN Rate Shaping"*. Whereas rate limiting discards packets when the traffic exceeds the the configured rate for the stream, rate shaping buffers packets for a limited period in order to attempt successful delivery.

A *traffic profile* is used to define the traffic characteristics before an upper limit is assigned. The traffic profile is created using an ACL, which can utilize any combination of the parameters supported in IP ACL. A rate limiting policy can then be defined by using the ACL and traffic rate limitations. You define the action to be taken on the traffic that exceeds the upper limit. For example, dropping packets. Except for port rate limiting, the rate limiting policy is then applied to a logical IP interface.

Rate limiting policies work only in one direction. That is, only the traffic coming into the interface to which a policy is applied will be subject to rate limiting (except for output port rate limiting policies, which are applied to egress ports). If both incoming and outgoing traffic to a network or subnet needs to be rate limited, then you should create separate policies to be applied to each interface.

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Note You can configure a maximum of 24 port and aggregate rate limiting policies per RS line card.

26.10.1 Rate Limiting Modes

Per-flow and flow-aggregate rate limiting is enabled on the RS by default. If you need to create aggregate or input port-level rate limiting policies, you must enable the aggregate rate limiting mode on each affected line card. If you enable aggregate rate limiting mode on a line card, you will not be able to apply new per-flow or flow-aggregate rate limiting policies to interfaces on that line card.

The rate limiting mode can be changed only if there are no existing rate limiting policies. For example, before you can enable aggregate rate limiting on a line card, you need to delete any existing per-flow or flow-aggregate rate limiting policies on that line card.

To enable aggregate or port-level rate limiting on a line card, enter the following command in Configure mode:

Enable aggregate rate limiting mode on an RS line card.	**`system enable aggregate-rate-limiting slot`** <*number*>

Note To change the rate limiting on the line card back to per-flow or flow-aggregate, negate the above command.

26.10.2 Per-Flow Rate Limiting

Use a per-flow rate limiting policy if an individual traffic flow needs to be limited to a particular rate. A single per-flow rate limiting policy can have multiple ACLs to define different traffic profiles and traffic rate limitations. When there are multiple traffic profiles, a sequence number is used to identify the order in which the profiles are applied.

Note Per-flow rate limiting is enabled on the RS by default. If you enable aggregate rate limiting on a particular line card, you cannot apply per-flow rate limiting policies for ports on that line card.

Note You cannot use non-IP ACLs for per-flow rate limit policies.

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To define a per-flow rate limit policy and apply the policy to an interface, enter the following commands in Configure mode:

Define a per-flow rate limit policy.	**rate-limit** *<name>* **input acl** *<acl list>* **rate** *<rate-limit>* **exceed-action drop-packets | set-priority-low | set-priority-medium | set-priority-high** [**sequence** *<number>*]
Apply a per-flow rate limit profile to an interface.	**rate-limit** *<name>* **apply interface** *<interface>* **| all**

26.10.3 Software-Based Flow-Aggregate Rate Limiting

Use a flow-aggregate rate limiting policy if an aggregation of flows needs to be limited to a particular rate. For example, you can use aggregate rate limiting to rate limit traffic to or from a particular subnet. You do not need to enable aggregate rate limiting mode on the line card (see Section 26.10.1, *"Rate Limiting Modes"*) to use flow-aggregate rate limiting.

Note You cannot use non-IP ACLs for flow-aggregate rate limit policies.

To define a flow-aggregate rate limit policy use the following commands in the Configure mode:

Define a software-based flow-aggregate rate limit policy.	**rate-limit** *<name>* **flow-aggregate acl** *<acl list>* **rate** *<rate-limit>* **exceed-action drop-packets | set-priority-low | set-priority-medium | set-priority-high sequence** *<number>* **min-bandwidth** *<bandwidth>* **distribute-among** *<flows>*
Apply a flow-aggregate rate limit policy to an interface.	**rate-limit** *<name>* **apply interface** *<interface>* **| all**

26.10.4 Port Rate Limiting

Use a port rate limiting policy if incoming or outgoing traffic on a particular port needs to be rate limited. Unlike other types of rate limiting policies, you do not specify an ACL when defining this type of policy. Port rate limiting policies do not need to be applied to an interface and take effect when they are created.

To configure port rate limiting policies for input ports, you must first enable the aggregate rate limiting mode on the line card (see Section 26.10.1, *"Rate Limiting Modes"*). You do not need to enable the aggregate rate limiting mode to configure a policy to limit outgoing traffic on a port. You can configure port-level rate limiting policies on output ports in either per-flow or aggregate rate limiting mode.

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To define a port rate limit policy, use the following commands in the Configure mode:

Define a port rate limit policy to limit incoming traffic on a port.	**rate-limit** *<name>* **port-level input rate** *<rate-limit>* **port** *<port list>* {**drop-packets | no-action | lower-priority | lower-priority-except-control | tos-precedence-rewrite** *<val1>* **| tos-precedence-rewrite-lower-priority** *<val2>*}
Define a port rate limit policy to limit outgoing traffic on a port.	**rate-limit** *<name>* **port-level output port** *<port list>* **rate** *<rate-limit>* **drop-packets**

Note that for output port policies, the only action that you can specify if traffic exceeds the specified rate is to drop packets.

If you configure output port policies, all types of outgoing IP traffic will be rate limited, including control traffic. If you do not want control traffic to be subject to rate limiting, enter the following command in the Configure mode:

Specify that control traffic is not subject to output port rate limiting.	**rate-limit** *<name>* **port-level slot** *<slot-number>* **ignore-control-priority**

Because you specify a slot number in the above command, output port rate limiting policies on any port on the specified slot will not be applied to control traffic.

26.10.5 Aggregate Rate Limiting

Use an aggregate rate limiting policy if an aggregation of flows needs to be limited to a particular rate. For example, you can use aggregate rate limiting to rate limit traffic to or from a particular subnet.

Note You cannot apply an aggregate rate limiting policy to an interface that spans ports on more than one line card. For example, you cannot apply an aggregate rate limiting policy to the interface *ip2*, if it interfaces to a VLAN that consists of ports et.1.(1-4) and et.2.(1-4).

To configure aggregate rate limiting policies, you must first enable aggregate rate limiting mode on the line card (see Section 26.10.1, *"Rate Limiting Modes"*).

Note You cannot use non-IP ACLs for aggregate rate limit policies.

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To define an aggregate rate limit policy and apply the policy to an interface, use the following commands in the Configure mode:

Define an aggregate rate limit policy.	**rate-limit** <*name*> **aggregate acl** <*acl list*> **rate** <*rate-limit*> {**drop-packets	no-action	lower-priority	lower-priority-except-control	tos-precedence-rewrite** <*val1*> **| tos-precedence-rewrite-lower-priority** <*val2*>} [**allocate-resources during-apply	during-traffic**]
Apply an aggregate rate limit policy to an interface.	**rate-limit** <*name*> **apply interface** <*interface*> **| all**

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26.10.6 Example Configurations

This section includes examples of rate limiting policy configurations.

Per-Flow Rate Limiting

The following is an example of configuring per-flow rate limiting on the RS.

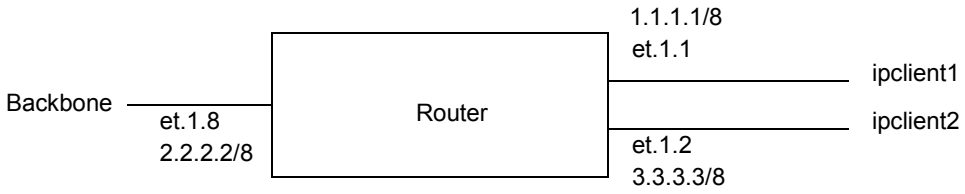

Figure 26-5 Per-flow rate limiting

Traffic from two interfaces, *ipclient1* with IP address 1.2.2.2 and *ipclient2* with IP address 3.1.1.1, is restricted to 10 Mbps for each flow with the following configuration:

```
vlan create client1 ip
vlan create backbone ip
vlan create client2 ip
vlan add ports et.1.1 to client1
vlan add ports et.1.2 to client2
vlan add ports et.1.8 to backbone
interface create ip ipclient1 vlan client1 address-netmask 1.1.1.1/8
interface create ip ipclient2 vlan client2 address-netmask 3.3.3.3/8
interface create ip backbone vlan backbone address-netmask 2.2.2.2/8
acl 100 permit ip 1.2.2.2
acl 200 permit ip 3.1.1.1
rate-limit client1 input acl 100 rate 10000000 exceed-action drop-packets
rate-limit client2 input acl 200 rate 10000000 exceed-action drop-packets
rate-limit client1 apply interface ipclient1
rate-limit client2 apply interface ipclient2
```

Flow-Aggregate Rate Limiting

In the following example, traffic from the subnetwork 122.132.0.0/16 to the Internet will be rate limited to 256 Kbps while traffic to the subnetwork will be rate limited to 64 Kbps.

```
acl cust1 permit ip any 122.132.0.0/16
acl cust1 permit ip 122.132.0.0/16 any
rate-limit cust1 flow-aggregate acl cust1 rate 256000 exceed-action drop-packets
min-bandwidth 4000
rate-limit apply cust1 interface tonet
rate-limit cust1 flow-aggregate acl cust1 rate 64000 exceed-action drop-packets
min-bandwidth 2000
rate-limit apply cust1 interface in1
```


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Aggregate Rate Limiting

In the following example, incoming FTP and HTTP traffic to the subnetwork 122.132.0.0/16 will be rate limited to 4 Mbps and 2 Mbps, respectively:

```
system enable aggregate-rate-limiting slot 1
interface create ip engintf address-netmask 122.132.10.23/16 port et.1.6
acl engftp permit ip 122.132.0.0/16 any any 20
rate-limit engftp aggregate acl engftp rate 4000000 drop-packets
acl enghttp permit ip 122.132.0.0/16 any any 80
rate-limit enghttp aggregate acl enghttp rate 2000000 drop-packets
rate-limit engftp apply interface engintf
rate-limit enghttp apply interface engintf
```

In the above example, the first configuration command is needed to enable the aggregate rate limiting mode on the line card in slot 1 (per-flow is the default rate limiting mode).

26.10.7 Displaying Rate Limit Information

To show information about rate limit policies, use the following command in the Enable mode:

Show rate limit policy information.	**rate-limit show all | policy-type** <*type*> | **policy-name** <*name*> **| interface** <*interface*> **|** {**port-level** <*port*> | <*name*>} **| rate-limiting-mode**

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27 PERFORMANCE MONITORING

The RS is a full wire-speed layer-2, 3 and 4 switching router. As packets enter the RS, layer-2, 3, and 4 flow tables are populated on each line card. The flow tables contain information on performance statistics and traffic forwarding. Thus the RS provides the capability to monitor performance at Layer 2, 3, and 4.

Layer-2 performance information is accessible to SNMP through MIB-II and can be displayed by using the **`l2-tables`** command in the CLI. Layer-3 and 4 performance statistics are accessible to SNMP through RMON/RMON2 and can be displayed by using the **`statistics show`** command in the CLI. In addition to the monitoring commands listed, you can find more monitoring commands listed in each chapter of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

To access statistics on the RS, enter the following commands in Enable mode:

Show DVMRP routes.	**`dvmrp show routes`**
Show all TCP/UDP connections and services.	**`ip show connections`**
Show all IP routes.	**`ip show routes`**
Show all IPX routes.	**`ipx show tables routing`**
Show all MAC addresses currently in the L2 tables.	**`l2-tables show all-macs`**
Show info about MACs residing in a port's L2 table.	**`l2-tables show port-macs`** <*port-list*>
Show all L2 flows (for ports in flow-bridging mode.	**`l2-tables show all-flows`**
Show information about the master MAC table.	**`l2-tables show mac-table-stats`**
Show information about a particular MAC address.	**`l2-tables show mac`**
Show info about multicasts registered by IGMP.	**`l2-tables show igmp-mcast-registrations`**
Show whether IGMP is on or off on a VLAN.	**`l2-tables show vlan-igmp-status`**
Show info about MACs registered by the system.	**`l2-tables show bridge-management`**
Show SNMP statistics.	**`snmp show statistics`**
Show ICMP statistics.	**`statistics show icmp`**
Show IP interface's statistics.	**`statistics show ip`**
Show unicast routing statistics.	**`statistics show ip-routing`**
Show IPX statistics.	**`statistics show ipx`**
Show IPX interface's statistics.	**`statistics show ipx-interface`**
Show IPX routing statistics.	**`statistics show ipx-routing`**

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Show multicast statistics.	**statistics show multicast**
Show port error statistics.	**statistics show port-errors**
Show potential physical layer errors.	**statistics show phy-errors**
Show port normal statistics.	**statistics show port-stats**
Show RMON etherStats statistics.	**statistics show rmon**
Show traffic summary statistics.	**statistics show summary-stats**
Show most active tasks.	**statistics show top**
Show TCP statistics.	**statistics show tcp**
Show UDP statistics.	**statistics show udp**
Show TACACS server statistics.	**tacacs show stats**
Show broadcast monitoring information for ports.	**port show bmon [config][detail][port** <*port list*>**][stats]**
Show all VLANs.	**vlan list**

27.1 CONFIGURING THE RS FOR PORT MIRRORING

The RS allows you to monitor activity with port mirroring. Port mirroring allows you to monitor the performance and activities of ports on the RS or for traffic defined by an ACL through just a single, separate port. While in Configure mode, you can configure your RS for port mirroring with a simple command line like the following:

Configure port mirroring.	**port mirroring monitor-port** <*port number*> **target-port** <*port list*>|*target-profile* <*acl name*>

Note Port mirroring is available for WAN ports. However, you cannot configure port mirroring on a port-by-port basis. (You can only configure port mirroring for the entire WAN card).

Only IP ACLs can be specified for port mirroring.

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27.2 MONITORING BROADCAST TRAFFIC

The RS allows you to monitor broadcast traffic for one or more ports, and for the control module. You can specify that a port be shut down if its broadcast traffic reaches a certain rate limit for a particular period of time. Additionally, you can configure the RS to shut down for a specified period, if the packets sent to the control module reach a certain limit during a specified time interval. Packets to be monitored can be limited to broadcast packets only or all packets.

To specify the monitoring of broadcast traffic and the shut down threshold for one or more ports, enter the following command in Configure mode:

Configure monitoring of broadcast traffic.	**port bmon** <*port list*> **rate** <*number*> **duration** <*number*> **shutdown** <*number*> **packets-limited all|broadcast**

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28 RMON CONFIGURATION

You can employ Remote Network Monitoring (RMON) in your network to help monitor traffic at remote points on the network. With RMON, data collection and processing is done with a remote *probe*, namely the RS. The RS also includes RMON *agent* software that communicates with a network management station via SNMP. Because information is only transmitted from the RS to the management station when required, SNMP traffic on the network and the management station's processing load are reduced.

The RS provides support for both RMON 1 and RMON 2 MIBs, as specified in RFCs 1757 and 2021, respectively. While non-RMON SNMP products allow the monitoring and control of specific network *devices*, RMON 1 returns statistics on network *segments* at the MAC layer. RMON 2 collects statistics on network and application layer *traffic* to show host-to-host connections and the applications and protocols being used. For example, the RMON 2 network layer matrix MIB group can show protocol-specific traffic between pairs of systems which can help to diagnose protocol problems. Note that RMON 2 is not a superset of RMON 1; on the RS, you can configure both RMON 1 and RMON 2 statistics collection.

28.1 CONFIGURING AND ENABLING RMON

By default, RMON is disabled on the RS. To configure and enable RMON on the RS, follow these steps:

1. Turn on the Lite, Standard, or Professional RMON groups by entering the **`rmon set lite|standard|professional`** command. You can also configure default control tables for the Lite, Standard, or Professional RMON groups by including the **`default-tables yes`** parameter.
2. Enable RMON on specified ports with the **`rmon set ports`** command.
3. Optionally, you can configure control tables for the Lite, Standard, or Professional RMON groups. For example, if you chose *not* to create default control tables for the Lite, Standard, or Professional groups, you can configure control table entries for specific ports on the RS.
4. Use the **`rmon enable`** command to enable RMON on the RS.

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28.1.1 Example of RMON Configuration Commands

The following are examples of the commands to configure and enable RMON on the RS:

```
 1 : port flow-bridging et.5.(3-8) *
     !
 2 : interface add ip en0 address-netmask 10.50.6.9/16
     !
 3 : system set contact "usama"
 4 : system set location Riverstone Networks, Inc.
 5 : system set name "rs"
      !
 6 : rmon set ports all-ports
 7 : rmon set lite default-tables yes
 8 : rmon set standard default-tables yes
     !
     ! Set RMON Pro Group with Default Tables ON, cap memory at 4 meg
     ! Pro: protocolDir, protocolDist, addressMap, al/nl-Matrix, al/nl-Host,
     ! al/nl-matrixTopN. userHistory, probeConfig.
     ! Default Tables: one control row per dataSource for protocolDist,
     ! addressMap, al/nl-Host, al/nl-Matrix.
     !
 9 : rmon set professional default-tables yes
10 : rmon set memory 4
11 : rmon enable
```

*. To collect layer 2 matrix information, port must be configured for flow-bridging mode. By default, ports on the RS operate in address-bridging mode.

The next sections describe Lite, Standard, and Professional RMON groups and control tables.

28.1.2 RMON Groups

The RMON MIB groups are defined in RFCs 1757 (RMON 1) and 2021 (RMON 2). On the RS, you can configure one or more levels of RMON support for a set of ports. Each level—Lite, Standard, or Professional—enables different sets of RMON groups (described later in this section). You need to configure at least one level before you can enable RMON on the RS.

To specify the support level for RMON groups, use the following CLI command line in Configure mode:

Specifies Lite, Standard, or Professional RMON groups.	**rmon set lite|standard|professional default-tables yes|no**

To specify the ports on which RMON is to be enabled, use the following CLI command line in Configure mode:

Specifies the ports on which RMON is enabled.	**rmon set ports** *<port list>***|allports**

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You can configure each level of RMON support independently of each other with default tables on or off. For example, you can configure Lite with default tables on for ports et.1.(1-8) and then configure Standard with no default tables for the same ports. You cannot configure Lite on one set of ports and Standard on another set of ports.

Lite RMON Groups

This section describes the RMON groups that are enabled when you specify the Lite support level. The Lite RMON groups are shown in the table below.

Table 28-1 Lite RMON groups

Group	Function
EtherStats	Records Ethernet statistics (for example, packets dropped, packets sent, etc.) for specified ports.
Event	Controls event generation and the resulting action (writing a log entry or sending an SNMP trap to the network management station).
Alarm	Generates an event when specified alarm conditions are met.
History	Records statistical samples for specified ports.

Standard RMON Groups

This section describes the RMON groups that are enabled when you specify the Standard support level. The Standard RMON groups are shown in the table below.

Table 28-2 Standard RMON groups

Group	Function
Host	Records statistics about the hosts discovered on the network.
Host Top N	Gathers the top n hosts, based on a specified rate-based statistic. This group requires the hosts group.
Matrix	Records statistics for source and destination address pairs.
Filter	Specifies the type of packets to be matched and how and where the filtered packets should flow (the channel).
Packet Capture	Specifies the capture of filtered packets for a particular channel.

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Professional RMON Groups

The Professional RMON groups correspond to the RMON 2 groups defined in RFC 2021. While RMON 1 groups allow for the monitoring of packets at the MAC layer, RMON 2 groups focus on monitoring traffic at the network and application layers.

The Professional RMON groups are shown in the table below.

Table 28-3 Professional RMON groups

Group	Function
Protocol Directory	Contains a list of protocols supported by the RS and monitored by RMON. See the RMON 2 Protocol Directory appendix in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.
Protocol Distribution	Records the packets and octets for specified ports on a per protocol basis.
Application Layer Host	Monitors traffic at the application layer for protocols defined in the protocol directory.
Network Layer Host	Monitors traffic at the network layer for protocols defined in the Protocol Directory.
Application Layer Matrix (and Top N)	Monitors traffic at the application layer for protocols defined in the Protocol Directory. Top N gathers the top n application layer matrix entries.
Network Layer Matrix (and Top N)	Monitors traffic at the network layer for protocols defined in the Protocol Directory. Top N gathers the top n network layer matrix entries.
Address Map	Records MAC address to network address bindings discovered for specified ports.
User History	Records historical data on user-defined statistics.

28.1.3 Control Tables

Many RMON groups contain both control and data tables. Control tables specify what statistics are to be collected. For example, you can specify the port for which statistics are to be collected and the owner (name, phone, or IP address) for that port. You can change many of the entries in a control table with **rmon** commands. Data tables contain the collected statistics. You cannot change any of the entries in a data table; you can only view the data.

When you specify the Lite, Standard, or Professional RMON groups, you have the option of creating default control tables. A default control table creates a control table entry for every port on the RS. Creating default control tables essentially configures data collection for every port on the RS for certain RMON groups. If you do not want this, you can choose not to create the default control tables and then configure the appropriate control tables for the data you wish to collect. Even if you use the default control tables, you can always use the **rmon** commands to modify control table entries.

If you choose to create default control tables, entries are created in the control tables for each port on the RS for the following groups:

Lite groups: Etherstats
History

Standard groups: Host
Matrix

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Professional groups: Protocol Distribution
Address Map
Application Layer/Network Layer Host
Application Layer/Network Layer Matrix

A row in the control table is created for each port on the RS, with the owner set to “monitor”. If you want, you can change the owner by using the appropriate **rmon** command. See the section Section 28.3, *"Configuring RMON Groups"* in this chapter for more the command to configure a specific group.

Note Control tables other than the default control tables must be configured with CLI commands, as described in Section 28.3, *"Configuring RMON Groups"*.

28.2 USING RMON

RMON on the RS allows you to analyze network traffic patterns, set up alarms to detect potential problems before they turn into real congestive situations, identify heavy network users to assess their possible candidacy for moves to dedicated or higher speed ports, and analyze traffic patterns to facilitate more long-term network planning.

RMON 1 provides layer 2 information. Traffic flowing through the RS’s layer 2 ASIC is collected by RMON 1 groups. RMON 2 in the RS provides layer 3 traffic information for IP and IPX protocols. Traffic flowing through the RS’s layer 3 ASIC is collected by RMON 2 groups. The RS’s RMON 2 protocol directory contains over 500 protocols that can be decoded for UDP and TCP ports. You can use RMON to see the kinds of protocol traffic being received on a given port.

For example, use the **rmon show protocol-distribution** command to see the kinds of traffic received on a given port:

```
rs# rmon show protocol-distribution et.5.5
RMON II Protocol Distribution Table

Index: 506, Port: et.1.7, Owner: monitor
      Pkts     Octets   Protocol
      ----     ------   --------
        19       1586   ether2
        19       1586   ether2.ip-v4
        19       1586   *ether2.ip-v4
         2        192   *ether2.ip-v4.icmp
        17       1394   *ether2.ip-v4.tcp
        17       1394   *ether2.ip-v4.tcp.www-http
```

In the example output above, only HTTP and ICMP traffic is being received on this port.

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To find out which host or user is using these applications/protocols on this port, use the following command:

```
rs# rmon show al-matrix et.5.5
RMON II Application Layer Host Table

Index: 500, Port: et.5.5, Inserts: 4, Deletes: 0, Owner: monitor
SrcAddr         DstAddr            Packets     Octets  Protocol
-------         -------            -------     ------  --------
10.50.89.88     15.15.15.3            1771     272562  *ether2.ip-v4
10.50.89.88     15.15.15.3            1125     211192  *ether2.ip-v4.tcp
10.50.89.88     15.15.15.3            1122     210967  *ether2.ip-v4.tcp.telnet
10.50.89.88     15.15.15.3               3        225  *ether2.ip-v4.tcp.www-http
```

28.3 CONFIGURING RMON GROUPS

As mentioned previously, control tables in many RMON groups specify the data that is to be collected for the particular RMON group. If the information you want to collect is in the default control tables, then you only need to turn on the default tables when you specify the RMON groups (Lite, Standard, or Professional); you do not need to configure entries in the default tables.

The following table shows the **rmon** command that you use to configure each RMON group:

To configure the Address Map group.	**rmon address-map index** <*index-number*> **port** <*port*> **[owner** <*string*>**] [status enable|disable]**
To configure the Application Layer Matrix top n entries.	**rmon al-matrix-top-n index** <*index-number*> **matrix-index** <*number*> **ratebase terminal-packets|terminal-octets| all-packets|all-octets duration** <*number*> **size** <*number*> **[owner** <*string*>**] [status enable|disable]**
To configure the Alarm group.	**rmon alarm index** <*index-number*> **variable** <*string*> **[interval** <*seconds*>**] [falling-event-index** <*num*>**] [falling-threshold** <*num*>**] [owner** <*string*>**] [rising-event-index** <*num*>**] [rising-threshold** <*num*>**] [startup rising|falling|both] [status enable|disable] [type absolute-value|delta-value]**
To configure the Packet Capture group.	**rmon capture index** <*index-number*> **channel-index**<*number*> **[full-action lock|wrap] [slice-size** <*number*>**] [download-slice-size** <*number*>**] [download-offset** <*number*>**] [max-octets** <*number*>**] [owner <string>] [status enable|disable]**

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To configure the Filter group, you must configure both the Channel and Filter control tables.	**rmon channel index** <*index-number*> **port** <*port*> **[accept-type matched|failed] [data-control on|off] [turn-on-event-index** <*number*>**] [turn-off-event-index** <*number*>**] [event-index** <*number*>**] [channel-status ready|always-ready][description** <*string*>**] [owner** <*string*>**] [status enable|disable]** **rmon filter index** <*index-number*> **channel-index** <*number*> **[data-offset** <*number*>**] [data** <*string*>**] [data-mask** <*string*>**] [data-not-mask** <*string*>**] [pkt-status** <*number*>**] [status-mask** <*number*>**] [status-not-mask** <*number*>**] [owner** <*string*>**] [status enable|disable]**
To configure the Etherstats group.	**rmon etherstats index** <*index-number*> **port** <*port*> **[owner** <*string*>**] [status enable|disable]**
To configure the Event group.	**rmon event index** <*index-number*> **type none|log|trap|both [community** <*string*>**] [description** <*string*>**] [owner** <*string*>**] [status enable|disable]**
To configure the History group.	**rmon history index** <*index-number*> **port** <*port*> **[interval** <*seconds*>**] [owner** <*string*>**] [samples** <*num*>**] [status enable|disable]**
To configure the Application Layer and Network Layer Host groups.	**rmon hl-host index** <*index-number*> **port** <*port*> **nl-max-entries** <*number*> **al-max-entries** <*number*> **[owner** <*string*>**] [status enable|disable]**
To configure the Application Layer and Network Layer Matrix groups.	**rmon hl-matrix index** <*index-number*> **port** <*port*> **nl-max-entries** <*number*> **al-max-entries** <*number*> **[owner** <*string*>**] [status enable|disable]**
To configure the Host group.	**rmon host index** <*index-number*> **port** <*port*> **[owner** <*string*>**] [status enable|disable]**
To configure the Host Top N entries.	**rmon host-top-n index** <*index-number*> **host-index** <*number*> **[base** <*statistics*>**] [duration** <*time*>**] [size** <*size*>**] [owner** <*string*>**] [status enable|disable]**
To configure the Matrix group.	**rmon matrix index** <*index-number*> **[port** <*port*>**] [owner** <*string*>**] [status enable|disable]**
To configure the Network Layer Matrix top n entries.	**rmon nl-matrix-top-n index** <*index-number*> **matrix-index** <*number*> **ratebase terminal-packets|terminal-octets|all-packets|all-octets duration** <*number*> **size** <*number*> **[owner** <*string*>**] [status enable|disable]**

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To configure the Protocol Distribution group.	**rmon protocol-distribution index** <*index-number*> **port** <*port*> **[owner** <*string*>**] [status enable|disable]**
To configure the User History group, you must configure the group of objects to be monitored and apply the objects in the group to the User History control table.	**rmon user-history-control index** <*index-number*> **objects** <*number*> **samples** <*number*> **interval** <*number*> **[owner** <*string*>**] [status enable|disable]** **rmon user-history-objects** <*groupname*> **variable** <*oid*> **type absolute|delta [status enable|disable]** **rmon user-history-apply** <*groupname*> **to** <*user-history-index*>

28.3.1 Configuration Examples

This section shows examples of configuration commands that specify an event that generates an SNMP trap and the alarm condition that triggers the event.

The RMON Alarm group allows the RS to poll itself at user-defined intervals. Alarms that constitute an event are logged into the Event table that can then be polled by the management station. The management station is able to poll more network devices this way, as it only needs to poll the RMON Event table and not the device itself. The management station can also be sent trap information.

The following examples configure the RS to create an event when a module is hot swapped into the chassis or any new IP interface is configured. The managed object ifTableLastChanged from RFC 2233) has an object identifier (OID) of 1.3.6.1.2.1.31.1.5.0 and the RS will poll this OID every 5 minutes (300 seconds).

The command line below is an example of an RMON Event group configuration with the following attributes:

- Index number 15 to identify this entry in the Event control table.
- The event is both logged in the Event table and an SNMP trap generated with the community string "public".
- Event owner is "help desk".

```
rs#(config) rmon event index 15 type both community public description "Interface added
or module hot swapped in" owner "help desk"
```

The command line below is an example of an RMON Alarm group configuration with the following attributes:

- Index number 20 to identify this entry in the Alarm control table.
- The OID 1.3.6.1.2.1.31.1.5.0 identifies the attribute to be monitored.
- Samples taken at 300 second (5 minute) intervals.
- A "Startup" alarm generation condition instructing the RS to generate an alarm if the sample is greater than or equal to the rising threshold or less than or equal to the falling threshold.
- Compare value at time of sampling (absolute value) to the specified thresholds.
- Rising and falling threshold values are 1.

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- Rising and falling event index values are 15, which will trigger the previously-configured Event.

```
rs#(config) rmon alarm index 20 variable 1.3.6.1.2.1.31.1.5.0 interval 300
startup both type absolute-value rising-threshold 1 falling-threshold 1
rising-event-index 15 falling-event-index 15 owner "help desk"
```

28.4 DISPLAYING RMON INFORMATION

The CLI **rmon show** commands allow you to display the same RMON statistics that can be viewed from a management station. To display RMON statistics for the RS, use the following CLI command lines in Enable mode:

[l]To show Ethernet statistics.	**rmon show etherstats** <*port-list*>**|all-ports**
To show all events and logs.	**rmon show events**
To show all alarms.	**rmon show alarms**
To show histories and logs.	**rmon show history** <*port-list*>**|all-ports**
To show hosts and logs.	**rmon show hosts** <*port-list*>**|all-ports [summary]**
To show all Host Top N and logs.	**rmon show host-top-n**
To show matrices and logs.	**rmon show matrix** <*port-list*>**|all-ports**
To show all channels.	**rmon show channels**
To show all filters.	**rmon show filters**
To show all packet captures and logs.	**rmon show packet-capture**
To display the RMON 2 Protocol Directory.	**rmon show protocol-directory**
To display the RMON 2 Protocol Distribution.	**rmon show protocol-distribution** <*port-list*>**|all-ports**
To display the RMON 2 Address Map table.	**rmon show address-map** <*port-list*>**|all-ports**
To show Network Layer Host logs.	**rmon show nl-host**<*port-list*>**|all-ports [summary]**
To show Application Layer Host logs.	**rmon show al-host**<*port-list*>**|all-ports [summary]**
To show Network Layer Matrix logs.	**rmon show nl-matrix**<*port-list*>**|all-ports [order-by srcdst|dstsrc] [summary]**
To show Application Layer Matrix logs.	**rmon show al-matrix**<*port-list*>**|all-ports [order-by srcdst|dstsrc] [summary]**
To show all Network Layer Matrix Top N.	**rmon show nl-matrix-top-n**
To show all Application Layer Matrix Top N.	**rmon show al-matrix-top-n**

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To show all user history logs.	**rmon show user-history**
To show probe configuration.	**rmon show probe-config [basic] [net-config] [trap-dest]**

[1]To display Ethernet statistics and related statistics for WAN ports, RMON has to be activated on that port. To activate RMON on a port, use the **frame-relay define service** or **ppp define service** command, and the **frame-relay apply service** or **ppp apply service** command. For additional information, refer to Section 30.4.2, *"Setting up a Frame Relay Service Profile"* (for frame relay) and Section 30.8.2, *"Setting up a PPP Service Profile"* (for PPP).

28.4.1 RMON CLI Filters

Because a large number of statistics can be collected for certain RMON groups, you can define and use CLI filters to limit the amount of information displayed with the **rmon show** commands. An RMON CLI filter can only be applied to a current Telnet or Console session.

The following shows Host table output *without* a CLI filter:

```
rs# rmon show hosts et.5.4
RMON I Host Table

Index: 503, Port: et.5.4, Owner: monitor
Address           InPkts   InOctets    OutPkts  OutOctets   Bcst   Mcst
-------           ------   --------    -------  ---------   ----   ----
00001D:921086          0          0        102       7140      0      0
00001D:9D8138       1128      75196        885     114387      0      0
00001D:A9815F          0          0        102       7140      0      0
00105A:08B98D          0          0        971     199960      0      0
004005:40A0CD          0          0         51       3264      0      0
006083:D65800          0          0       2190     678372      0      0
0080C8:E0F8F3          0          0        396      89818      0      0
00E063:FDD700          0          0        104      19382      0      0
01000C:CCCCCC       2188     678210          0          0      0      0
01005E:000009        204      14280          0          0      0      0
0180C2:000000       1519      97216          0          0      0      0
030000:000001        168      30927          0          0      0      0
080020:835CAA        885     114387       1128      75196      0      0
980717:280200          0          0       1519      97216      0      0
AB0000:020000          2        162          0          0      0      0
FFFFFF:FFFFFF       1354     281497          0          0      0      0
```


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The following shows the same **rmon show hosts** command with a filter applied so that only hosts with inpkts greater than 500 are displayed:

```
rs# rmon apply cli-filter 4
rs# rmon show hosts et.5.4
RMON I Host Table
Filter: inpkts > 500
Address       Port        InPkts   InOctets    OutPkts  OutOctets   Bcst   Mcst
-------       ----        ------   --------    -------  ---------   ----   ----
00001D:9D8138 et.5.4        1204      80110        941     121129      0      0
01000C:CCCCCC et.5.4        2389     740514          0          0      0      0
0180C2:000000 et.5.4        1540      98560          0          0      0      0
080020:835CAA et.5.4         940     121061       1204      80110      0      0
FFFFFF:FFFFFF et.5.4        1372     285105          0          0
```

RMON CLI filters can only be used with the following groups:

- Hosts
- Matrix
- Protocol Distribution
- Application Layer Host
- Network Layer Host
- Application Layer Matrix
- Network Layer Matrix

Creating RMON CLI Filters

To create RMON CLI filters, use the following CLI command in Configure mode:

Creates an RMON CLI filter.	**rmon set cli-filter** *<filter-id> <parameter>*

Using RMON CLI Filters

To see and use RMON CLI filters, use the following CLI command in User or Enable mode:

Displays RMON CLI filters.	**rmon show cli-filters**
Applies a CLI filter on current Telnet or Console session.	**rmon apply cli-filters** *<filter-id>*
Clears the currently-selected CLI filter.	**rmon clear cli-filter**

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28.5 TROUBLESHOOTING RMON

If you are not seeing the information you expected with an **rmon show** command, or if the network management station is not collecting the desired statistics, first check that the port is up. Then, use the **rmon show status** command to check the RMON configuration on the RS.

Check the following fields on the **rmon show status** command output:

```
rs# rmon show status
RMON Status
-----------
* RMON is ENABLED ❶
* RMON initialization successful.

             ❷
+--------------------------+
| RMON Group Status        |
+-------+--------+---------+
| Group | Status | Default |
+-------+--------+---------+
| Lite  |     On |     Yes |   ❹
+-------+--------+---------+
| Std   |     On |     Yes |
+-------+--------+---------+
| Pro   |     On |     Yes |
+-------+--------+---------+

RMON is enabled on: et.5.1, et.5.2, et.5.3, et.5.4, et.5.5, et.5.6, et.5.7, et.5.8 ❸

RMON Memory Utilization
-----------------------
        Total Bytes Available:   48530436

Total Bytes Allocated to RMON:    4000000
             Total Bytes Used:    2637872    ❺
             Total Bytes Free:    1362128
```

1. Make sure that RMON has been enabled on the RS. When the RS is booted, RMON is off by default. RMON is enabled with the **rmon enable** command.
2. Make sure that at least one of the RMON support levels—Lite, Standard, or Professional—is turned on with the **rmon set lite|standard|professional** command.
3. Make sure that RMON is enabled on the port for which you want statistics. Use the **rmon set ports** command to specify the port on which RMON will be enabled.
4. Make sure that the control table is configured for the report that you want. Depending upon the RMON group, default control tables may be created for all ports on the RS. Or, if the RMON group is not one for which default control tables can be created, you will need to configure control table entries using the appropriate **rmon** command.

   If you or your application are unable to create a control table row, check the **snmp show status** output for errors. Make sure that there is a read-write community string. Verify that you can ping the RS and that no ACLs prevent you from using SNMP to access the RS.
5. Make sure that RMON has not run out of memory.

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28.6 ALLOCATING MEMORY TO RMON

RMON allocates memory depending on the number of ports enabled for RMON, the RMON groups that have been configured, and whether or not default tables have been turned on or off. Enabling RMON with all groups (Lite, Standard, and Professional) with default tables uses approximately 300 Kbytes per port. If necessary, you can dynamically allocate additional memory to RMON.

To display the amount of memory that is currently allocated to RMON, use the following CLI command in Enable mode:

Displays the memory allocated to RMON.	**rmon show status**

Any memory allocation failures are reported. The following is an example of the information shown with the **rmon show status** command:

```
rs# rmon show status
RMON Status
-----------
* RMON is ENABLED
* RMON initialization successful.

+--------------------------+
| RMON Group Status |
+-------+--------+---------+
| Group | Status | Default |
+-------+--------+---------+
| Lite  |     On |     Yes |
+-------+--------+---------+
| Std   |     On |     Yes |
+-------+--------+---------+
| Pro   |     On |     Yes |
+-------+--------+---------+

RMON is enabled on: et.5.1, et.5.2, et.5.3, et.5.4, et.5.5, et.5.6, et.5.7, et.5.8

RMON Memory Utilization
-----------------------
        Total Bytes Available:     48530436
Total Bytes Allocated to RMON:     4000000
             Total Bytes Used:     2637872
             Total Bytes Free:     1362128
```

To set the amount of memory allocated to RMON, use the following CLI command in User or Enable mode:

Specifies the total amount of Mbytes of memory allocated to RMON.	**rmon set memory** <*number*>

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The maximum amount of memory that you can allocate to RMON depends upon the RS model, as shown in the table below.

Table 28-4 Maximum memory allocations to RMON

RS platform	Maximum memory
RS 32000	96 MB
RS 8600	48 MB
RS 8000	24 MB
RS 3000, RS 2100, RS 2000, RS 1000	12 MB

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29 LFAP CONFIGURATION GUIDE

29.1 OVERVIEW

The Lightweight Flow Accounting Protocol (LFAP) agent, as originally defined in RFC 2124, is a TCP-oriented protocol used to push accounting information collected on the RS to a flow accounting server. The LFAP agent uses ACLs to determine the IP traffic on which accounting information will be collected.

Traffic accounting in the network can help with the following:

- Capacity planning
- Application usage tracking
- Cost apportioning by user or department
- Server and resource usage

Traffic accounting is not intended for troubleshooting immediate network problems, enforcing company policies, or replacing the accounts payable system.

Note For a complete list of LFAP related commands, see the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

29.2 REQUIREMENTS

- LFAP agent — Available on RS switch routers
- Server that understands LFAP (a simple server can be downloaded from *www.nmops.org*)

29.3 TRAFFIC ACCOUNTING SERVICES

Riverstone's Accounting Services consists of the following components:

- LFAP agent on the RS that collects application flow accounting information and sends it to the Riverstone accounting server. You can configure the RS to collect information on an entire interface or on a specific host-to-host application flow. Configuring the LFAP agent on the RS is described in this chapter.

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- One or more accounting servers. The main responsibility of the accounting server is to listen for LFAP messages from the RS on the network and collect the information. A single accounting server can collect data from multiple RS.
- Optional 3rd party billing/accounting application.

Figure 29-1 shows the interactions between LFAP on the RS, the accounting server, and a third party billing and accounting application.

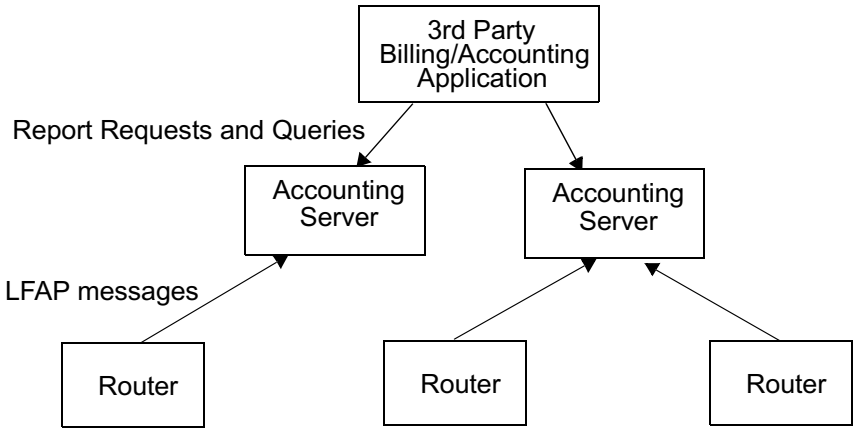

Figure 29-1 Riverstone's network traffic accounting services

29.4 CONFIGURING THE LFAP AGENT ON THE RS

Because the accounting server-to-RS connection is through TCP, LFAP messages can be transmitted across a LAN or a WAN. However, if you are deploying traffic accounting to save backbone or WAN bandwidth, it makes sense to have the accounting server as close as possible to the RS that it manages.

Up to three accounting servers can be configured on a RS, although the RS can only send LFAP messages to a single accounting server at a time. The first configured accounting server is the *primary*, so the RS attempts to connect to it via TCP first. If the connection fails, then the next configured accounting server is tried. An accounting server can be configured as the primary accounting server for one group of RS and the secondary accounting server for another group of RS.

To configure and enable LFAP on a RS:

1. Configure the ACL rules for the accounting policy and apply the ACL to one or more interfaces:

```
rs(config)# acl 101 permit ip any any any any accounting 15-minutes
rs(config)# acl 101 apply interface all-ip input output logging off
policy local
```

Note The **accounting** parameter must be followed by one of the three *checkpoint* time interval parameters: **5-minutes**, **15-minutes**, or **hourly**.

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The **accounting 15-minutes** keyword tells the accounting server what size flow records to create. It does not affect the RS. For example, the **accounting 15-minutes** keyword causes the accounting server to break flows on exact 15 minute boundaries (e.g. 10:00, 10:15, 10:30, etc.). This allows the billing application to calculate a bit rate. For example, the application could ask for all records in the 10:00 to 10:15 slot, sum the bytes and divide by 900 to get bits/second during that period.

Note This feature is not currently supported on the simple server located at *www.nmsops.org*.

2. Identify the primary (and secondary) accounting server system to which the RS will send LFAP messages (up to three accounting servers can be configured)

:

```
rs(config)# lfap set server 134.141.170.82
```

3. Start the LFAP protocol on the RS:

```
rs(config)# lfap start
```

29.5 MONITORING THE LFAP AGENT ON THE RS

The **lfap show** commands display information about the configuration of the LFAP agent on the RS and its current status. Use the following commands in Enable mode to view LFAP agent information

:

Table 29-1 LFAP monitoring commands

Command	Displays
lfap show configuration	Configuration of the LFAP agent on the RS.
lfap show servers	Configured accounting server(s) to which the LFAP agent could connect.
lfap show statistics	Statistics collected by the LFAP agent.
lfap show status	Server to which the LFAP agent is currently connected and the current status of the LFAP agent.
lfap show all	All of the above information.

Note LFAP information is also available through the RS's SNMP agent.

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30 WAN CONFIGURATION

This chapter provides an overview of:

- Wide Area Network (WAN) applications in Section 30.2, *"Configuring WAN Interfaces"*.
- Frame Relay configuration in Section 30.3, *"Frame Relay Overview"*.
- PPP configuration in Section 30.7, *"Point-to-Point Protocol (PPP) Overview"*.
- Channelized T1, E1 and T3 configurations in Section 30.16, *"Channelized T1, E1 and T3 Services Overview"*.
- Clear Channel T3 and E3 configurations inSection 30.17, *"Clear Channel T3 and E3 Services Overview"*.
- Inverse Multiplxer in Section 30.14, *"Inverse Multiplexer Overview"*.
- WAN rate shaping in Section 30.13, *"WAN Rate Shaping"*.
- Cisco HDLC protocol in Section 30.11, *"Cisco HDLC WAN Port Configuration"*. This protocol is for WAN routing with Cisco routers that use the Cisco HDLC protocol; it is the default protocol used for WAN on Cisco routers.

In addition, you can view the following:

- An example of multi-router WAN configurations in Section 30.15, *"WAN Configuration Examples"*.
- Example Channelized T1, E1 and T3 configurations in Section 30.18, *"Scenarios for Deploying Channelized T1, E1 and T3"*.
- Example Clear Channel T3 and E3 configurations in Section 30.19, *"Scenarios for Deploying Clear Channel T3 and E3"*.

The configuration and monitoring CLI commands are described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

30.1 HIGH-SPEED SERIAL INTERFACE (HSSI) AND STANDARD SERIAL INTERFACES

On the Riverstone RS Switch Router, WAN routing is performed over a serial interface using two basic protocols: Frame Relay and point-to-point protocol (PPP). The protocols have their own set of configuration and monitoring CLI commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

In both the Frame Relay and PPP environments on the RS, you can specify ports to be High-Speed Serial Interface (HSSI) or standard serial interface ports, depending, of course, on the type of hardware you have. Each type of interface plays a part in the nomenclature of port identification. You must use either the “hs.” or “se.” prefix for HSSI and serial interfaces, respectively, when specifying WAN port identities.

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For example, you would specify a frame relay serial WAN port located at router slot 4, port 1, on VC 100 as "se.4.1.100."

Using the same approach, a PPP high-speed serial interface (HSSI) WAN port located at router slot 3, port 2 would be identified as "hs.3.2."

30.2 CONFIGURING WAN INTERFACES

Configuring IP and IPX interfaces for the WAN is generally the same as for the LAN. You can configure IP/IPX interfaces on the physical port or you can configure the interface as part of a VLAN for WAN interfaces. However, in the case of IP interfaces, you can configure multiple IP addresses for each interface. Refer to Section 11.2, *"Configuring IP Interfaces and Parameters"* and Section 23.4, *"Configuring IPX Interfaces and Parameters"* for more specific information.

There are some special considerations that apply only to WAN interfaces. These are detailed in this section.

30.2.1 Primary and Secondary Addresses

Like LAN interfaces, WAN interfaces can have primary and secondary IP addresses. For Frame Relay, you can configure primary and secondary addresses which are static or dynamic. For PPP, however, the primary addresses may be dynamic or static, but the secondary addresses must be static. This is because the primary addresses of both the local and peer routers are exchanged during IPCP/IPXCP negotiation.

Note There is no mechanism in PPP for obtaining any secondary addresses from the peer.

30.2.2 Static, Mapped, and Dynamic Peer IP/IPX Addresses

The following sections describe the difference between static, mapped, and dynamic peer IP and IPX addresses and provide simple command line examples for configuration.

Static Addresses

If the peer IP/IPX address is known before system setup, you can specify the peer address when the interface is created. This disables Inverse ARP (InArp) for Frame Relay on that source/peer address pair. However, InArp will still be enabled for any other addresses on that interface or other interfaces. A static peer address for PPP means that the address the peer supplies during IP Control Protocol (IPCP) or IPX Control Protocol (IPXCP) negotiations will be ignored.

The following command line displays an example for a port:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 peer-address
10.50.1.2 port hs.3.1
```


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The following command line displays an example for a VLAN:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 peer-address
10.50.1.2 vlan BLUE
```

Mapped Addresses

Mapped peer IP/IPX addresses are very similar to static addresses in that InArp is disabled for Frame Relay and the address negotiated in IPCP/IPXCP is ignored for PPP.

Mapped addresses are most useful when you do not want to specify the peer address using the **interface create** command. This would be the case if the interface is created for a VLAN and there are many peer addresses on the VLAN. If any of the peers on the VLAN do not support InArp or IPCP/IPXCP, then use a mapped address to configure the peer address.

The following command lines display two examples for Frame Relay:

```
rs(config)# frame-relay set peer-address ip-address 10.50.1.1/16 ports se.4.1.204
```

```
rs(config)# frame-relay set peer-address ipx-address a1b2c3d4.aa:bb:cc:dd:ee:ff ports
se.6.3.16
```

The following command line displays two examples for PPP:

```
rs(config)# ppp set peer-address ip-address 10.50.1.1/16 ports se.4.1
```

```
rs(config)# ppp set peer-address ipx-address a1b2c3d4.aa:bb:cc:dd:ee:ff ports se.6.3
```

Dynamic Addresses

If the peer IP/IPX address is unknown, you do not need to specify it when creating the interface. When in the Frame Relay environment, the peer address will be automatically discovered via InArp. Similarly, the peer address will be automatically discovered via IPCP/IPXCP negotiation in a PPP environment.

The following command lines display examples for a port and a VC:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 port hs.3.1
```

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 port hs.5.2.19
```

The following command line displays an example for a VLAN:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 vlan BLUE
```


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30.2.3 Forcing Bridged Encapsulation

WAN for the RS has the ability to force bridged packet encapsulation. This feature has been provided to facilitate seamless compatibility with Cisco routers, which expect bridged encapsulation in certain operating modes.

The following command line displays an example for Frame Relay:

```
rs(config)# frame-relay set fr-encaps-bgd ports hs.5.2.19
```

The following command line displays an example for PPP:

```
rs(config)# ppp set ppp-encaps-bgd ports hs.5.2
```

30.2.4 Packet Compression

Packet compression can increase throughput and shorten the times needed for data transmission. You can enable packet compression for Frame Relay VCs and for PPP ports, however, both ends of a link must be configured to use packet compression.

Enabling compression on WAN serial links should be decided on a case by case basis. Important factors to consider include:

- Average packet size
- Nature of the data
- Link integrity
- Latency requirements

Each of these factors is discussed in more detail in the following sections and should be taken into consideration before enabling compression. Since the factors are dependent on the environment, you should first try running with compression histories enabled. If compression statistics do not show a very good long-term compression ratio, then select the “no history” option. If the compression statistics do not improve or show a ration of less than 1, then compression should be disabled altogether.

Average Packet Size

In most cases, the larger the packet size, the better the potential compression ratio. This is due to the overhead involved with compression, as well as the compression algorithm. For example, a link which always deals with minimum size packets may not perform as well as a link whose average packet size is much larger.

Nature of the Data

In general, data that is already compressed cannot be compressed any further. In fact, packets that are already compressed will grow even larger. For example, if you have a link devoted to streaming MPEG videos, you should not enable compression as the MPEG video data is already compressed.

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Link Integrity

Links with high packet loss or links that are extremely over-subscribed may not perform as well with compression enabled. If this is the situation on your network, you should *not* enable compression histories. This applies only to PPP compressions. In Frame Relay compression, histories are always used.

Compression histories take advantage of data redundancy *between* packets. In an environment with high packet loss or over-subscribed links, there are many gaps in the packet stream resulting in very poor use of the compression mechanism. Compression histories work best with highly-correlated packet streams. Thus, a link with fewer flows will generally perform better than a link with many flows when compression histories are utilized.

The "no history" (max-histories = 0) option causes packets to be compressed on a packet-by-packet basis, thus packet loss is not a problem. Also, the number of flows is not an issue with this option as there is no history of previous packets.

Latency Requirements

The use of compression may affect a packet's latency. Since the compressed packet is smaller, less time is needed to transmit it. On the other hand, each packet must undergo a compression/decompression process. Since the compression ratio will vary, the amount of latency will also vary.

Example Configurations

The following command line displays an example for Frame Relay:

```
rs(config)# frame-relay set payload-compress ports se.3.1.300
```

The following command line displays an example for PPP:

```
rs(config)# ppp set payload-compress port se.4.2
```

30.2.5 Packet Encryption

Packet encryption allows data to travel through unsecured networks. You can enable packet encryption for PPP ports, however, both ends of a link must be configured to use packet encryption.

The following command line displays an example:

```
rs(config)# ppp set payload-encrypt transmit-key 0x123456789abcdef receive-key
0xfedcba987654321 port se.4.2, mp.1
```

30.2.6 WAN Quality of Service

Increasing concentrations of audio, video, and data traffic are now presenting the networking industry with the significant challenge of employing the most effective use of WAN Quality-of-Service (QoS) as possible to ensure reliable end-to-end communication. For example, critical and time-sensitive traffic such as audio should have higher

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levels of bandwidth allocated than less time-sensitive traffic such as file transfers or e-mail. Simply adding more and more bandwidth to a network is not a viable solution to the problem. WAN access is extremely expensive, and there is a limited (albeit huge) supply. Therefore, making the most effective use of existing bandwidth is now a more critical issue than ever before.

The fact that IP communications to the desktop are clearly the most prevalent used today has made it the protocol of choice for end-to-end audio, video, and data applications. This means that the challenge for network administrators and developers has been to construct their networks to support these IP-based audio, video, and data applications along with their tried-and-true circuit-based applications over a WAN.

In addition, these audio, video, and data traffic transmissions hardly ever flow at a steady rate. Some periods will see relatively low levels of traffic, and others will temporarily surpass a firm's contracted Committed Information Rate (CIR). Carrier-based packet-switched networks such as Frame Relay and ATM are designed to handle these temporary peaks in traffic, but it is more cost- and resource- efficient to employ effective QoS configuration(s), thus relaxing the potential need to up your firm's CIR. By applying some of the following sorts of attributes to interfaces on your network, you can begin to shape your network's QoS configuration to use existing bandwidth more effectively.

Source Filtering and ACLs

Source filtering and ACLs can be applied to a WAN interface. However, they affect the entire module, not an individual port.

For example, if you want to apply a source MAC address filter to a WAN serial card located in slot 5, port 2, your configuration command line would look like the following:

```
rs(config)# filters add address-filter name wan1 source-mac 000102:030405 vlan 2
in-port-list se.5
```

Port se.5 is specified instead of se.5.2 because source filters affect the entire WAN module. Hence, in this example, **`source-mac 000102:030405`** would be filtered from ports se.5.1, se.5.2, se.5.3, and se.5.4 (assuming that you are using a four-port serial card).

ACLs work in a similar fashion. For example, if you define an ACL to deny all http traffic on one of the WAN interfaces, it will apply to the other WAN interfaces on that module as well. In practice, by making your ACLs more specific, for example by specifying source and destination IP addresses with appropriate subnet masks, you can achieve your intended level of control.

Weighted-Fair Queueing

Through the use of Weighted-Fair Queueing QoS policies, WAN packets with the highest priority can be allotted a sizable percentage of the available bandwidth and "whisked through" WAN interface(s). Meanwhile, the remaining bandwidth is distributed for "lower-priority" WAN packets according to the user's percentage-of-bandwidth specifications. Refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual* for more detailed configuration information.

Note Weighted-Fair Queueing applies only to best-effort traffic on the WAN card. If you apply any of the WAN specific traffic shaping commands, then weighted fair queuing will no longer be applicable.

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Congestion Management

One of the most important features of configuring the RS to ensure Quality of Service is the obvious advantage gained when you are able to avoid network congestion. The following topics touch on a few of the most prominent aspects of congestion avoidance when configuring the RS.

Random Early Discard (RED)

Random Early Discard (RED) allows network operators to manage traffic during periods of congestion based on policies. RED works with TCP to provide fair reductions in traffic proportional to the bandwidth being used. Weighted Random Early Discard (WRED) works with IP Precedence or priority, as defined in the **qos** configuration command line, to provide preferential traffic handling for higher-priority traffic.

The CLI commands related to RED in both the Frame Relay and PPP protocol environments allow you to set maximum and minimum threshold values for each of the low-, medium-, and high-priority categories of WAN traffic.

Adaptive Shaping

Adaptive shaping implements the congestion-sensitive rate adjustment function and has the following characteristics:

- No blocking of data flow under normal condition if the traffic rate is below Bc+Be.
- Reduction to a lower CIR upon detection of network congestion.
- Progressive return to the negotiated information transfer rate upon congestion abatement.

The CLI command related to adaptive shaping allows you to set threshold values for triggering the adaptive shaping function.

30.3 FRAME RELAY OVERVIEW

Frame relay interfaces are commonly used in a WAN to link several remote routers together via a single central switch. This eliminates the need to have direct connections between all of the remote members of a complex network, such as a host of corporate satellite offices. The advantage that Frame Relay offers to this type of geographic layout is the ability to switch packet data across the interfaces of different types of devices like switch-routers and bridges, for example.

Frame Relay employs the use of Virtual Circuits (VCs) when handling multiple logical data connections over a single physical link between different pieces of network equipment. The Frame Relay environment, by nature, deals with these connections quite well through its extremely efficient use of precious (sometimes scarce) bandwidth.

You can set up frame relay ports on your RS with the commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

30.3.1 Virtual Circuits

Think of a Virtual Circuit (VC) as a “virtual interface” (sometimes referred to as “sub-interfaces”) over which Frame Relay traffic travels. Frame Relay interfaces on the RS use one or more VCs to establish bidirectional, end-to-end connections with remote end points throughout the WAN. For example, you can connect a series of multi-protocol routers in various locations using a Frame Relay network.

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30.3.2 Permanent Virtual Circuits (PVCs)

WAN interfaces can take advantage of connections that assure a minimum level of available bandwidth at all times. These standing connections, called Permanent Virtual Circuits (PVCs), allow you to route critical packet transmissions from host to peer without concern for network congestion significantly slowing, let alone interrupting, your communications. PVCs are the most prevalent type of circuit used today and are similar to dedicated private lines in that you can lease and set them up through a service provider.

In a corporate setting, network administrators can use PVCs in an internal network to set aside bandwidth for critical connections, such as videoconferencing with other corporate departments.

30.4 CONFIGURING FRAME RELAY INTERFACES FOR THE RS

This section provides an overview of configuring a host of WAN parameters and setting up WAN interfaces. When working in the Frame Relay protocol environment, you must first define the type and location of the WAN interface. Having established the type and location of your WAN interfaces, you need to (optionally) define one or more service profiles for your WAN interfaces, then apply a service profile to the desired interface(s). An example of this process is covered in *"Frame Relay Port Configuration"*.

30.4.1 Defining the Type and Location of a Frame Relay and VC Interface

To configure a frame relay WAN port, you need to first define the type and location of one or more frame relay WAN ports or virtual circuits (VCs) on your RS. The following command line displays a simplified example of a frame relay WAN port definition:

Define the type and location of a frame relay WAN port.	**port set** <*port*> **wan-encapsulation frame-relay speed** <*number*>

Note If the port is a HSSI port that will be connected to a HSSI port on another router, you can also specify **clock** <*clock-source*> in your definition.

Then, you must set up a frame relay virtual circuit (VC). The following command line displays a simplified example of a VC definition:

Define the type and location of a frame relay VC.	**frame-relay create vc port** <*port*>

30.4.2 Setting up a Frame Relay Service Profile

Once you have defined the type and location of your Frame Relay WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for Frame Relay communications.

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Note The RS comes with a set of "default values" for Frame Relay interface configuration settings, which means that setting up a Frame Relay service profile is not absolutely necessary to begin sending and receiving Frame Relay traffic on your RS.

After you configure one or more service profiles for your Frame Relay interface(s), you can then apply a service profile to active Frame Relay WAN ports, specifying their behavior when handling Frame Relay traffic. The following command line displays all of the possible attributes used to define a Frame Relay service profile:

Define a frame relay service profile.	**frame-relay define service** <*service name*> [**Bc** <*number*>] [**Be** <*number*>] [**becn-adaptive-shaping** <*number*>] [**cir** <*number*>] [**high-priority-queue-depth** <*number*>] [**low-priority-queue-depth** <*number*>] [**med-priority-queue-depth** <*number*>] [**red on | off**] [**red-maxTh-high-prio-traffic** <*number*>] [**red-maxTh-low-prio-traffic** <*number*>] [**red-maxTh-med-prio-traffic** <*number*>] [**red-minTh-high-prio-traffic** <*number*>] [**red-minTh-low-prio-traffic** <*number*>] [**red-minTh-med-prio-traffic** <*number*>] [**rmon on | off**]

30.4.3 Applying a Service Profile to an Active Frame Relay WAN Port

Once you have created one or more frame relay service profiles, you can specify their use on one or more active frame relay WAN ports on the RS. The following command line displays a simplified example of this process:

Apply a service profile to an active WAN port.	**frame-relay apply service** <*service name*> **ports** <*port list*>

30.5 MONITORING FRAME RELAY WAN PORTS

Once you have configured your frame relay WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in Enable mode:

Display a particular frame relay service profile	**frame-relay show service** <*service name*>
Display all available frame relay service profiles	**frame-relay show service all**
Display the last reported frame relay error	**frame-relay show stats ports** <*port name*> **last-error**
Display active frame relay LMI parameters	**frame-relay show stats ports** <*port name*> **lmi**
Display MIBII statistics for frame relay WAN ports	**frame-relay show stats ports** <*port name*> **mibII**
Display a summary of all LMI statistics	**frame-relay show stats ports** <*port name*> **summary**

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30.6 FRAME RELAY PORT CONFIGURATION

To configure frame relay WAN ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a typical frame relay WAN interface specification.

To define the location and identity of a serial frame relay WAN port located at slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set se.5.1 wan-encapsulation frame-relay speed 45000000
```

To define the location and identity of a High-Speed Serial Interface (HSSI) VC located at slot 4, port 1 with a DLC of 100:

```
rs(config)# frame-relay create vc port hs.4.1.100
```

Suppose you wish to set up a service profile called "profile1" that includes the following characteristics:

- Committed burst value of 2 million and excessive burst value of 1 million
- BECN active shaping at 65 frames
- Committed information rate (CIR) of 20 million bits per second
- Leave high-, low-, and medium-priority queue depths set to factory defaults
- Random Early Discard (RED) disabled
- RMON enabled

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# frame-relay define service profile1 Bc 2000000 Be 10000000
becn-adaptive-shaping 65 cir 20000000 red off rmon on
```

To assign the above service profile to the VC interface created earlier (slot 4, port 1):

```
rs(config)# frame-relay apply service profile1 ports hs.4.1.100
```

30.7 POINT-TO-POINT PROTOCOL (PPP) OVERVIEW

Because of its ability to quickly and easily accommodate IP and IPX protocol traffic, Point-to-Point Protocol (PPP) routing has become a very important aspect of WAN configuration. Using PPP, you can set up router-to-router, host-to-router, and host-to-host connections.

Establishing a connection in a PPP environment requires that the following events take place:

- The router initializing the PPP connection transmits Link Control Protocol (LCP) configuration and test frames to the remote peer to set up the data link.
- Once the connection has been established, the router which initiated the PPP connection transmits a series of Network Control Protocol (NCP) frames necessary to configure one or more network-layer protocols.

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- Finally, when the network-layer protocols have been configured, both the host and remote peer can send packets to one another using any and all of the configured network-layer protocols.

The link will remain active until explicit LCP or NCP frames instruct the host and/or the peer router to close the link, or until some external event (i.e., user interruption or system time-out) takes place.

You can set up PPP ports on your RS with the commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

30.7.1 Use of LCP Magic Numbers

LCP magic numbers enable you to detect situations where PPP LCP packets are looped back from the remote system, resulting in an error message. The use of LCP magic numbers is enabled on the RS by default. However, should you employ a service profile in which the use of LCP magic numbers has been disabled, undetected “loopback” behavior may become a problem.

Note In the event that a PPP WAN interface remains unrecognized at startup due to loopback interference, you can use the **ppp restart** command in the CLI to remedy the situation.

30.8 CONFIGURING PPP INTERFACES

This section provides an overview of configuring a host of WAN parameters and setting up WAN interfaces. When working in the PPP environment, you must first define the type and location of your WAN interfaces. Having established the type and location of your WAN interfaces, you need to (optionally) define one or more service profiles for your WAN interfaces, then apply a service profile to the desired interface(s). Examples of this process are displayed in *"PPP Port Configuration"*.

30.8.1 Defining the Type and Location of a PPP Interface

To configure a PPP WAN port, you need to first define the type and location of one or more PPP WAN ports on your RS. The following command line displays a simplified example of a PPP WAN port definition:

Define the type and location of a PPP WAN port.	**port set** <*port*> **wan-encapsulation ppp speed** <*number*>

If the port is an HSSI port that will be connected to a HSSI port on another router, you can specify **clock** <*clock-source*> in the definition.

30.8.2 Setting up a PPP Service Profile

Once you have defined the type and location of your PPP WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for PPP communications.

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Note The RS comes with a set of default values for PPP interface configuration settings, which means that setting up a PPP service profile is not absolutely necessary to begin sending and receiving PPP traffic on your RS.

After you configure one or more service profiles for your PPP interface(s), you can then apply a service profile to active PPP WAN ports, specifying their behavior when handling PPP traffic. The following command line displays all of the possible attributes used to define a PPP service profile:

Define a PPP service profile.	**ppp define service** <*service name*> [**bridging enable | disable ip enable | disable ipx enable | disable**] [**high-priority-queue-depth** <*number*>] [**lcp-echo on | off**] [**lcp-magic on | off**] [**low-priority-queue-depth** <*number*>] [**max-configure** <*number*>] [**max-failure** <*number*>] [**max-terminate** <*number*>] [**med-priority-queue-depth** <*number*>] [**red on | off**] [**red-maxTh-high-prio-traffic** <*number*>] [**red-maxTh-low-prio-traffic** <*number*>] [**red-maxTh-med-prio-traffic** <*number*>] [**red-minTh-high-prio-traffic** <*number*>] [**red-minTh-low-prio-traffic** <*number*>] [**red-minTh-med-prio-traffic** <*number*>] [**retry-interval** <*number*>] [**rmon on | off**]

Note If it is necessary to specify a value for bridging, IP, and/or IPX, you must specify all three of these values at the same time. You cannot specify just one or two of them in the command line without the other(s).

30.8.3 Applying a Service Profile to an Active PPP Port

Once you have created one or more PPP service profiles, you can specify their use on one or more active PPP ports on the RS. The following command line displays a simplified example of this process:

Apply a service profile to an active WAN port.	**ppp apply service** <*service name*> **ports** <*port list*>

30.8.4 Configuring Multilink PPP Bundles

The Multilink PPP (MLP) standard defines a method for grouping multiple physical PPP links into a logical pipe, called an "MLP bundle." PPP ports are bundled together on a single WAN module. Large packets are fragmented and transmitted over each physical link in an MLP bundle. At the destination, MLP reassembles the packets and places them in their correct sequence.

Note If you have a four-port Channelized T3 card, this is regarded as two separate WAN modules. Ports 1 and 2 are on one WAN module, and ports 3 and 4 are on the other WAN module. Therefore, you cannot add all four ports to a single MLP bundle.

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The following table describes the commands for configuring MLP:

Add PPP port(s) to an MLP bundle.	**ppp add-to-mlp** *<mlp>* **port** *<port list>*
Create MLP bundle(s).	**ppp create-mlp** *<mlp list>* **slot** *<number>*
Set MLP encapsulation format.	**ppp set mlp-encaps-format ports** *<port list>* **[format short-format]**
Set the size of frames that fragmented for transmission on an MLP bundle.	**ppp set mlp-frag-size ports** *<port list>* **size** *<size>*
Set the depth of the queue used to hold MLP packets for preserving the packet order.	**ppp set mlp-orderq-depth ports** *<port list>* **qdepth** *<number-of-packets>*
Set the depth of the queue used to hold packet fragments for reassembly.	**ppp set mlp-fragq-depth ports** *<port list>* **qdepth** *<number-of-packets>*

Compression on MLP Bundles or Links

Compression can be applied on either a bundle or link basis if MLP is enabled on PPP links. If compression is enabled on a bundle, the packets will be compressed *before* processing by MLP. If compression is enabled on a link, the packets will be compressed *after* the MLP processing.

In general, choose bundle compression over link compression whenever possible. Compressing packets before they are "split" by MLP is much more efficient for both the compression algorithm and the WAN card. Link compression is supported to provide the widest range of compatibility with other vendors' equipment.

30.9 MONITORING PPP WAN PORTS

Once you have configured your PPP WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in the Enable mode:

Display a particular PPP service profile.	**ppp show service** *<service name>*
Display all available PPP service profiles.	**ppp show service all**
Display bridge NCP statistics for specified PPP WAN port.	**ppp show stats port** *<port name>* **bridge-ncp**
Display IP NCP statistics for specified PPP WAN port.	**ppp show stats ports** *<port name>* **ip-ncp**
Display link-status statistics for a specified PPP WAN port.	**ppp show stats ports** *<port name>* **link-status**
Displays information for PPP ports that are added to MLP bundles.	**ppp show mlp** *<mlp list>* **| all-ports**

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30.10 PPP PORT CONFIGURATION

To configure PPP WAN ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a typical PPP WAN interface specification.

To define the location and identity of a High-Speed Serial Interface (HSSI) PPP WAN port located at router slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set hs.5.1 wan-encapsulation ppp speed 45000000
```

When configuring a PPP connection between two multi-vendor equipment, make sure that the maximum transfer unit (MTU) and the maximum receive unit (MRU) are compatible for each machine. For instance, if Router1 has an MTU=4k/MRU=4k and Router2 has an MTU=9k/MRU=9k, there will be incompatibility issues and the PPP connection may fail. This is because Router1 cannot accommodate the bigger amount of traffic from Router2.

To set the MRU=10k and MTU=10k on the HSSI port hs.5.1:

```
rs(config)# port set hs.5.1 mtu 10000 mru 10000
```

Suppose you wish to set up a service profile called "profile2" that includes the following characteristics:

- Bridging enabled
- Leave high-, low-, and medium-priority queue depths set to factory defaults
- IP and IPX enabled
- Sending of LCP Echo Requests disabled
- Use of LCP magic numbers disabled
- The maximum allowable number of unanswered requests set to 8
- The maximum allowable number of negative-acknowledgment transmissions set to 5
- The maximum allowable number of unanswered/improperly answered connection-termination requests before declaring the link to a peer lost set to 4
- Random Early Discard disabled
- The number of seconds between subsequent configuration request transmissions (the "retry interval") set to 25
- RMON enabled

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# ppp define service profile2 bridging enable ip enable ipx
enable lcp-echo off lcp-magic off max-configure 8 max-failure 5
max-terminate 4 red off retry-interval 25 rmon on
```

To assign the above service profile to the active PPP WAN port defined earlier (slot 5, port 1):

```
rs(config)# ppp apply service profile2 ports hs.5.1
```


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30.11 CISCO HDLC WAN PORT CONFIGURATION

To configure Cisco HDLC ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a Cisco HDLC WAN interface specification.

To define the location and identity of a High-Speed Serial Interface (HSSI) Cisco HDLC WAN port located at router slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set hs.5.1 wan-encapsulation cisco-hdlc speed 45000000
```

When you apply cisco-hdlc encapsulation on a WAN port, a default service profile is used. This service profile uses the default values of the profile parameters. If you want to apply a non-default service profile, then you must create a profile and apply it to the port.

30.11.1 Setting up a Cisco HDLC Service Profile

Once you have defined the type and location of your Cisco HDLC WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for Cisco HDLC communications.

Note The RS comes with a set of "default values" for Cisco HDLC interface configuration settings, which means that setting up a Cisco HDLC service profile is not absolutely necessary to begin sending and receiving Cisco HDLC traffic on your RS.

Suppose you wish to set up a service profile called "ciscosp" that includes the following characteristics:

- Leave high-, low-, and medium-priority queue depths set to factory defaults
- Random Early Discard disabled
- The number of seconds between "keepalive" messages set to 15
- RMON enabled

30.11.2 Applying a Service Profile to an Active Cisco HDLC WAN Port

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# cisco-hdlc define service ciscosp red off keepalive 15 rmon on
```

To assign the above service profile to the active Cisco HDLC port defined earlier (slot 5, port 1):

```
rs(config)# cisco-hdlc apply service ciscosp ports hs.5.1
```


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30.11.3 Assigning IP Addresses to a Cisco HDLC WAN Port

The interface address of the local Cisco HDLC WAN port and peer address must conform to the following rules:

1. The interface and peer addresses should belong to the same subnet.
2. The host part of the addresses should be either 1 or 2. If the host part of the interface address is 1, then the peer address should be 2, and vice-versa.

For example on routers RS1 and RS2, in subnet 123.45.67.0, the configuration is:

```
! RS1 Cisco HDLC WAN port
rs1(config)# interface create ip cisco_hdlc address-netmask 123.45.6.1/24
peer-address 123.45.67.2 port hs.5.1
```

```
! RS2 Cisco HDLC WAN port
rs2(config)# interface create ip cisco_hdlc address-netmask 123.45.6.2/24
peer-address 123.45.67.1 port hs.3.2
```

30.11.4 Monitoring Cisco HDLC Port Configuration

Once you have configured your Cisco HDLC WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in the Enable mode:

Display a particular Cisco HDLC service profile.	**cisco-hdlc show service** <*service name*>
Display all available Cisco HDLC service profiles.	**cisco-hdlc show service all**
Display statistics for Cisco HDLC WAN port(s).	**cisco-hdlc show stats ports** <*port name*> **| all-ports** [**summary**]
Clear the specified statistics counter on one or more Cisco HDLC WAN ports.	**cisco-hdlc clear stats-counter** [**frame-drop-qdepth-counter**] [**max-frame-enqued-counter**] [**frame-drop-red-counter**] [**rmon**] **port** <*port-list*>

30.12 CISCO HDLC CONFIGURATION EXAMPLE

HSSI ports 1 and 2 in slot 5 are configured for Cisco HDLC encapsulation, and a speed of 45Mbps. A service profile "s1" is then created with the Keepalive set to 15 seconds, and RED disable. Finally, the service profile is applied to the HSSI ports:

```
rs(config)# port set hs.5.1,hs.5.2 wan-encapsulation cisco-hdlc speed 45000000
rs(config)# cisco-hdlc define service s1 keepalive 15 red off
rs(config)# cisco-hdlc apply service s1 ports hs.5.1,hs.5.2
```


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30.13 WAN RATE SHAPING

WAN rate shaping provides a way to send traffic from Ethernet ports out through a WAN port in a controlled and equitable manner. For instance, incoming traffic from several Ethernet ports enter the WAN network through a single serial port. Normally, the Ethernet flows would compete with each other for bandwidth through the serial port, resulting in congestion and dropped packets. WAN rate shaping controls the flow of outbound traffic through the WAN port by restricting bandwidth and using packet buffers.

Use WAN rate shaping with the following WAN line cards:

- WAN serial line card
- WAN High Speed Serial (HSSI) line card
- T1/E1 and T3/E3 line cards in unframed mode
- Clear Channel T3/E3 line card

WAN rate shaping is compatible with the following encapsulation schemes:

- Point-to-Point protocol (PPP)
- Cisco-based High Level Data Link Control protocol (Cisco-HDLC)
- Multi-link Point-to-Point protocol (MLPPP)

30.13.1 Configuring WAN Rate Shaping

Configure WAN rate shaping using the two commands **`wan define`** and **`wan apply`**. Use **`wan define`** to create a rate shaping template, then use **`wan apply`** to apply the template to a physical WAN port.

Rate shaping is defined using the following parameters:

Name	The name of the template used to identify it when applied to a WAN port.
Committed Information Rate (CIR)	The amount of outbound WAN port bandwidth in Kbps used by each flow
Committed Burst Size (Bc)	The number of bits that a flow can send through the WAN port during any sampling interval; the sampling interval is called the *Committed Rate Measurement Interval* (Tc)
Excess Burst Size (Be)	The number of bits that a flow can send through the WAN port in excess of Bc if there is unutilized WAN port bandwidth (Be is optional)

Note The RS calculates the sampling interval (Tc) automatically, using the equation Tc = Bc / CIR.

In the example below, a WAN rate shaping template named "*WanTemp1*" is defined with CIR = 64 Kbps, Bc = 4000 bits, and Be = 2000 bits:

```
rs(config)# wan define rate-shape-parameters WanTemp1 cir 64000 bc 4000 be 2000
```

The RS calculates the sampling interval to be Bc / CIR = 2000 bits / 64000 bps = 1/32 sec. = Tc.

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Note If Be is defined in a rate shaping template, a good rule of thumb is to set its value roughly equal to Bc / 2.

Use the **wan apply** command to apply the template to a WAN port. Specify Ethernet flows within the **wan apply** command using one of the following identifiers:

Destination IP address Any Ethernet flow attempting to reach this destination IP address is rate shaped according to the template.

Source IP address Any Ethernet flow with this source IP address is rate shaped according to the template.

Port number Any Ethernet flow originating from this physical port is rate shaped according to the template.

VLAN name Any Ethernet flow that is a member of this VLAN is rate shaped according to the template.

In the example below, the previously defined WAN rate shaping template (*WanTemp1*) is applied to a Clear Channel T3 WAN port, and the Ethernet flows to be rate shaped are identified by a source IP address:

```
rs(config)# wan apply rate-shape-parameters WanTemp1 port t3.3.1 source-ip-address
134.141.153.0/24
```

In the example above, notice that a subnet mask is specified with the source IP address. Adding the subnet mask causes the rate shaping template to be applied to all flows from the subnet 134.141.153.0. To apply rate shaping to a single source IP address, enter the IP address only, but do not specify a subnet mask.

The **wan apply** command also allows you to set the following parameters that affect rate shaping behavior:

burst-queue-depth The depth (in packets) of the queue used to buffer packets when Bc or Bc + Be are exceeded.

no-shape-high-priority Specifies that Ethernet traffic from the high-priority queue does not take part in rate shaping and transmits on the WAN port without bandwidth restrictions.

shape-control-priority Normally, control-priority traffic (ARP, OSPF, and so on) are not subjected to rate shaping. However, control-priority traffic is included in the rate shaping process if this parameter is specified.

Note Rate shaping control-priority traffic is not recommended.

30.13.2 The WAN Rate Shaping Algorithm

The first step in rate shaping traffic through a WAN port is to allot some percentage of the WAN port's bandwidth (in Kbps) to each Ethernet flow. This allotted bandwidth is called the Committed Information Rate (CIR). Generally, the total of the CIRs for all rate shaped flows should not exceed the total bandwidth of the WAN port. However, depending on the characteristics of each flow, some oversubscribing of WAN port bandwidth is usually permissible.

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Next, the number of bits from each rate-shaped Ethernet flow is measured as they pass through the WAN port. These measurements are taken during equal sampling intervals (Tc), which are some fraction of one second. During a sampling interval, if the number of bits from a flow exceeds a pre-set value, called the Committed Burst Size (Bc), the rate shaping algorithm stops the Ethernet flow from sending packets directly through the WAN port. Instead, packets are sent to a queue, and the queue is emptied at a rate that does not exceed Bc. Because Bc is never exceeded, at the end of one second, the rate shaped Ethernet flow transmits a number of bits less than or equal to CIR.

Note Queue depth is not unlimited. Each queue for each flow can buffer a maximum of 256 packets.

If the traffic through the WAN port is bursty and there are periods when WAN bandwidth is not 100 percent utilized, the rate shaping algorithm can allow each rate shaped Ethernet flow to exceed its Bc by a specified amount called the Excess Burst Size (Be). As with Bc, if during a sampling interval, a particular flow exceeds its allocated Be, packets are buffered until the bit rate for the flow falls to Bc + Be. However, note that Be is not guaranteed because the amount of excess bandwidth typically changes over time. Because of this dynamic nature of excess bandwidth, queuing also can occur if the amount of excess WAN bandwidth falls below Bc + Be.

Figure 30-1 demonstrates how the parameters CIR, Bc, Be, and the sampling rate (Tc) interact to perform rate shaping. Note that in the example, Bc and Be are set to some number of bits and Tc is equal to 1/16 of a second.

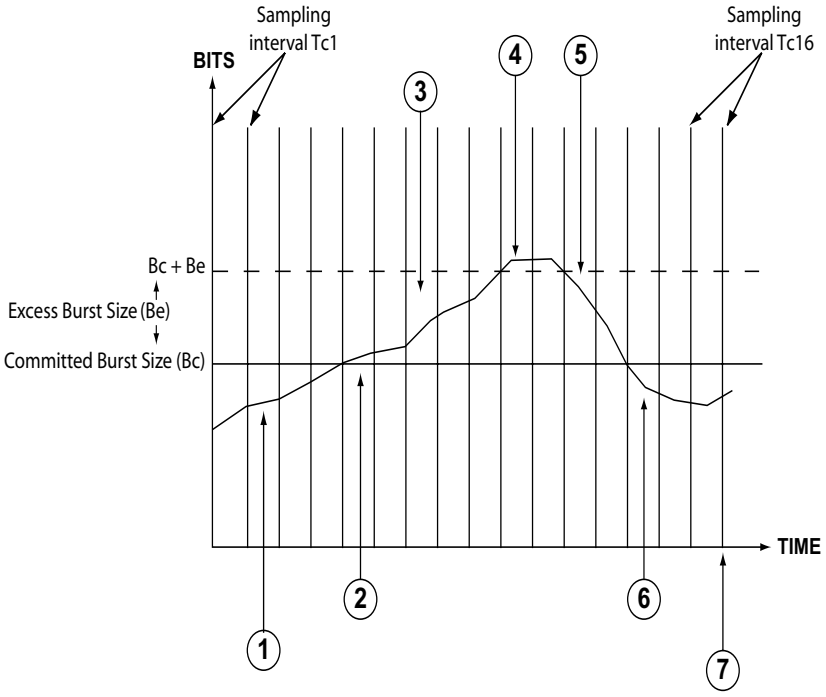

Figure 30-1 WAN rate shaping example

The following numbered list corresponds to the numbered points in Figure 30-1:

1. The number of bits sent through the WAN port during the sampling period Tc is less than Bc.

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2. The number of bits sent through the WAN port exceeds Bc. If Be is not defined or if there is no extra bandwidth available on the WAN interface, packets begin to be queued.
3. The number of bits sent through the WAN port exceeds Bc. This occurs only if Be is defined and there is extra bandwidth available.
4. The number of bits sent through the WAN port has exceeds Bc + Be, and packets are queued.
5. The number of bits sent through the WAN port drops below Bc + Be; as long as excess bandwidth is available, the queue begins to empty.
6. The number of bits sent through the WAN port drops below Bc, the buffer empties and packets are once again passed directly through the WAN port.
7. One second has elapsed (the sum of the sampling intervals), and the rate shaping algorithm has controlled the Ethernet flow so that the number of bits sent through the WAN port is approximately equal to CIR.

Notice that if Be is defined and excess bandwidth is available, the amount of WAN port bandwidth utilized by an Ethernet flow can exceed its specified CIR. In the best possible case, where there is sustained excess bandwidth, a flow's bandwidth can attain a maximum equal to ((Be + Bc) / Bc) * CIR. For example, if CIR = 128 Kbps, Bc = 4000, and Be = 2000, the calculated maximum bandwidth that the Ethernet flow could potentially reach is:

Max Bandwidth = ((2000 + 4000) / 4000) * 128000 = 192000 or 192 Kbps

30.13.3 WAN Rate Shaping Example

In this example, computers on three different floors are connected to R1 through Ethernet switches. R1 connects to the WAN through a Clear Channel T3 line. Rate shaping is applied, and limits each switch to 150 Kbps of bandwidth on the Clear Channel T3 line. Flows from each switch are identified by the physical port to which they connect on R1; these ports are **`et.2.1`**, **`et.2.7`**, and **`et.3.8`**. At the other end of the WAN connection, R2 passes Ethernet flows onto the Metro backbone. Conversely, R2 rate shapes Ethernet flows from the Metro backbone that originate on subnet 124.141.77.0/24 and sends them through its own Clear Channel T3 line to R1 (see Figure 30-2).

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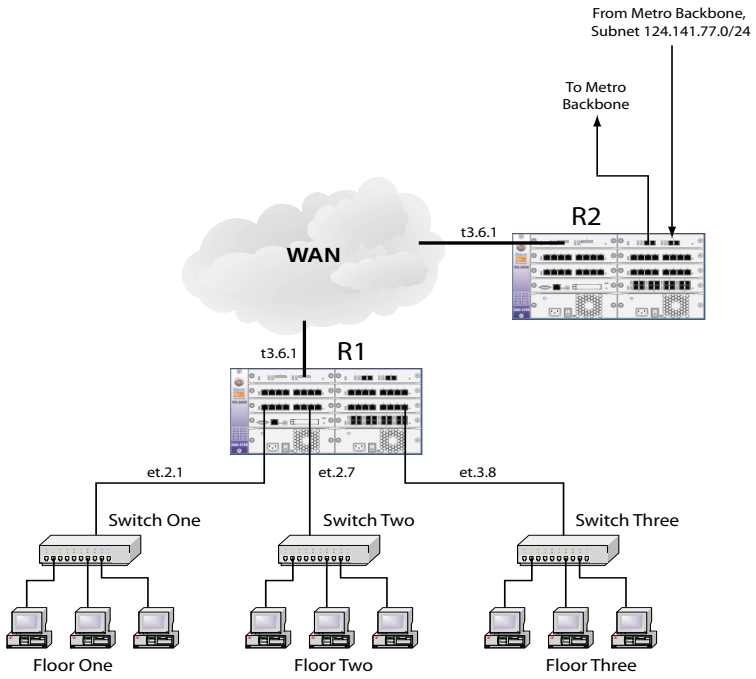

Figure 30-2 Rate shaping on destination IP address

First, the rate shaping template "*dest1"* is created on R1, with the rate shape parameters specified as CIR = 150 Kbps, Bc = 5000 bits, Be is unspecified, and R1 sets Tc automatically to Bc / CIR = 1/30 of a second:

```
rs(config)# wan define rate-shape-parameters dest1 cir 150000 bc 5000
```

Template *dest1* is applied to R1's Clear Channel T3 port for each port connected to an Ethernet switch:

```
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.2.1
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.2.7
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.3.8
```

Next, the rate shaping template "*dest2"* is created on R2, with the rate shape parameters specified as CIR = 170 Kbps, Bc = 7000 bits, Be is unspecified, and R2 sets Tc automatically to Bc / CIR = 1/24 of a second:

```
rs(config)# wan define rate-shape-parameters dest2 cir 170000 bc 7000
```

Template *dest2* is applied to R2's Clear Channel T3 port for traffic originating from subnet 124.141.77.0/24:

```
rs(config)# wan apply rate-shape-parameters dest2 port t3.6.1 source-ip-address
124.141.77.0/24
```


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Once the templates are applied, all Ethernet flows on R1 originating from ports et.2.1, et.2.7, and et.3.8 are rate shaped to a maximum of 150 kbps, while Ethernet flows on R2 originating from subnet 124.141.77.0 are rate shaped to a maximum of 170 Kbps in the opposite direction.

30.13.4 Using WAN Rate Shaping

The following section lists a few situations to keep in mind when using WAN rate shaping.

Using Multiple Rate Shaping Templates

The rate shaping algorithm can use only one identifier to determine whether an Ethernet flow should be rate shaped. Furthermore, the identifiers are tested against a flow in the following order:

1. Destination IP address
2. Source IP address
3. VLAN
4. Traffic source port

If more than one rate shaping template is applied to a WAN port, the first template with an identifier that matches an Ethernet flow's internal parameters (as shown in the ordered list above) is applied to the flow. Keep in mind this hierarchy of identifiers when configuring rate shaping to assure that Ethernet flows are rate shaped by the desired template.

For example, two templates are created (*temp1* and *temp2*), each with a different value for CIR and Bc:

```
rs(config)# wan define rate-shape-parameters temp1 cir 150000 bc 5000
rs(config)# wan define rate-shape-parameters temp2 cir 200000 bc 9000
```

Both templates are applied to a single Clear Channel T3 port, one using **traffic-source-port** as its identifier, the other using **vlan** as its identifier:

```
rs(config)# wan apply rate-shape-parameters temp1 port t3.2.1 traffic-source-port
et.1.2
rs(config)# wan apply rate-shape-parameters temp2 port t3.2.1 vlan west-district
```

Notice that **vlan** is higher in the identifier hierarchy than **traffic-source-port**. Because of this, the VLAN name is examined first. As a result, if **et.1.2** belongs to VLAN *west-district*, flows from port **et.1.2** will be shaped according to *temp2*, rather than *temp1*.

Rate Shaping by Best Effort

If CIR and Bc are both set to zero, and Be is set to some value greater than zero, packets from the Ethernet flow controlled by this template will pass through the WAN port only if there is surplus bandwidth equal to or greater than Be. This configuration does not provide any guarantee that the flow's packets will get through the WAN port; and bandwidth for this flow is attained only on a best-effort basis.

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Performing Rate Limiting

If the **`burst-queue-depth`** is set to zero for a particular template, WAN rate shaping for the affected flows effectively becomes *rate limiting*. This switch to rate limiting occurs because without a queue, packets are simply dropped whenever the bit rate of a flow reaches Bc and/or Be.

Non-Rate Shaped Flows

If Ethernet flows that are not controlled by a WAN rate shaping template are mixed with flows that are controlled. The non-rate shaped flows will disregard the rate shaped flows and take as much bandwidth as they can. For this reason, it's generally not a good idea to mix rate shaped and non-rate shaped flows on a WAN port.

Rate Shaping in Both Directions

WAN rate shaping works best when it is applied in both directions. In other words, if you apply rate shaping to an RS WAN port going into the WAN, you also should apply rate shaping to the RS WAN port at the other end of the connection. Applying rate shaping to each RS allows connection-oriented protocols, such as TCP, to communicate more efficiently and experience fewer instances that could potentially trigger crank-back.

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30.14 INVERSE MULTIPLEXER OVERVIEW

The Inverse Multiplexer (IMUX) feature allows the Riverstone RS Switch Router to inter-operate with those Cabletron Systems products that only support the WAN IMUX (Wide Area Networking Inverse Multiplexer) feature.

The RS Switch Router already implements a method of WAN link aggregation using Multilink PPP (MPPP) as detailed in RFC1990. The IMUX functionality is added as an extension to the MPPP functionality.

Note For bandwidth aggregation between multiple RS Switch Routers, and other vendors' products, the non-proprietary Multilink PPP feature should be used.

The IMUX link state protocol provides a simple mechanism to detect when a WAN link has failed and quickly removes the link from an IMUX group so that minimal disturbance to the flow of data occurs. The protocol also allows additional WAN links to be added dynamically to an IMUX group, to allow a greater aggregation of WAN bandwidth.

An IMUX group cannot be configured across multiple modules. For example, an IMUX group can consist of four T1 lines, which must all be on the same Multi-Rate WAN Module (that is, t1.2.1-4). Also, the MP bundle being configured for IMUX mode must first be configured to use bridged format encapsulation, using the **`ppp set ppp-encaps-bgd`** command.

The following configuration shows how to configure IMUX using the four T1 ports in slot 2:

```
rs(config)# port set t1.2.1-4:1 timeslots 1-24 wan-encapsulation ppp
rs(config)# ppp create-mlp mp.1 slot 2
rs(config)# ppp add-to-mlp mp.1 port t1.2.1-4:1
rs(config)# ppp set ppp-encaps-bgd ports mp.1
rs(config)# ppp set mlp-imux-mode ports mp.1
```

To check which ports have IMUX enabled (in this example, ports se.4.2 and se.4.3 are IMUX ports):

```
rs# ppp show stats ports all-ports summary
                    Link      IP       IPX    Bridge    Encr     Comp     Imux
                    Adm/Opr  Adm/Opr  Adm/Opr  Adm/Opr  Adm/Opr  Adm/Opr  Adm/Opr
Port                States   States   States   States   States   States   States
----                --/--    --/--    --/--    --/--    --/--    --/--    --/--
se.4.2      (mp.1) Up/Dn    Up/Dn    Up/Dn    Up/Dn    Dn/Dn    Dn/Dn    Up/Dn
se.4.3      (mp.1) Up/Dn    Up/Dn    Up/Dn    Up/Dn    Dn/Dn    Dn/Dn    Up/Dn
se.4.4              Up/Dn    Up/Dn    Up/Dn    Up/Dn    Dn/Dn    Dn/Dn    Dn/Dn
mp.1               Up/Dn    Up/Dn    Up/Dn    Up/Dn    Dn/Dn    Dn/Dn    Up/Dn

(L) denotes compression/encryption on an individual link
(M) denotes compression/encryption on the MLP bundle
```

30.14.1 Bit Error Rate Testing an IMUX Group

Bit Error Rate Testing (BERT) can only be performed on a single physical or logical port. To perform a BERT test on a port in an IMUX group, the port must first be removed from the group.

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30.15 WAN CONFIGURATION EXAMPLES

30.15.1 Simple Configuration File

The following is an example of a simple configuration file used to test frame relay and PPP WAN ports:

```
port set hs.5.1 wan-encapsulation frame-relay speed 45000000
port set hs.5.2 wan-encapsulation ppp speed 45000000
interface create ip fr1 address-netmask 10.1.1.1/16 port hs.5.1.100
interface create ip ppp2 address-netmask 10.2.1.1/16 port hs.5.2
interface create ip lan1 address-netmask 10.20.1.1/16 port et.1.1
interface create ip lan2 address-netmask 10.30.1.1/16 port et.1.2
ip add route 10.10.0.0/16 gateway 10.1.1.2
ip add route 10.40.0.0/16 gateway 10.2.1.2
```

For a broader, more application-oriented WAN configuration example, see *"Multi-Router WAN Configuration"* next.

30.15.2 Multi-Router WAN Configuration

The following is a diagram of a multi-router WAN configuration encompassing three subnets. From the diagram, you can see that R1 is part of both Subnets 1 and 2, R2 is part of both Subnets 2 and 3, and R3 is part of subnets 1 and 3. You can click on the router label (in blue) to jump to the actual text configuration file for that router:

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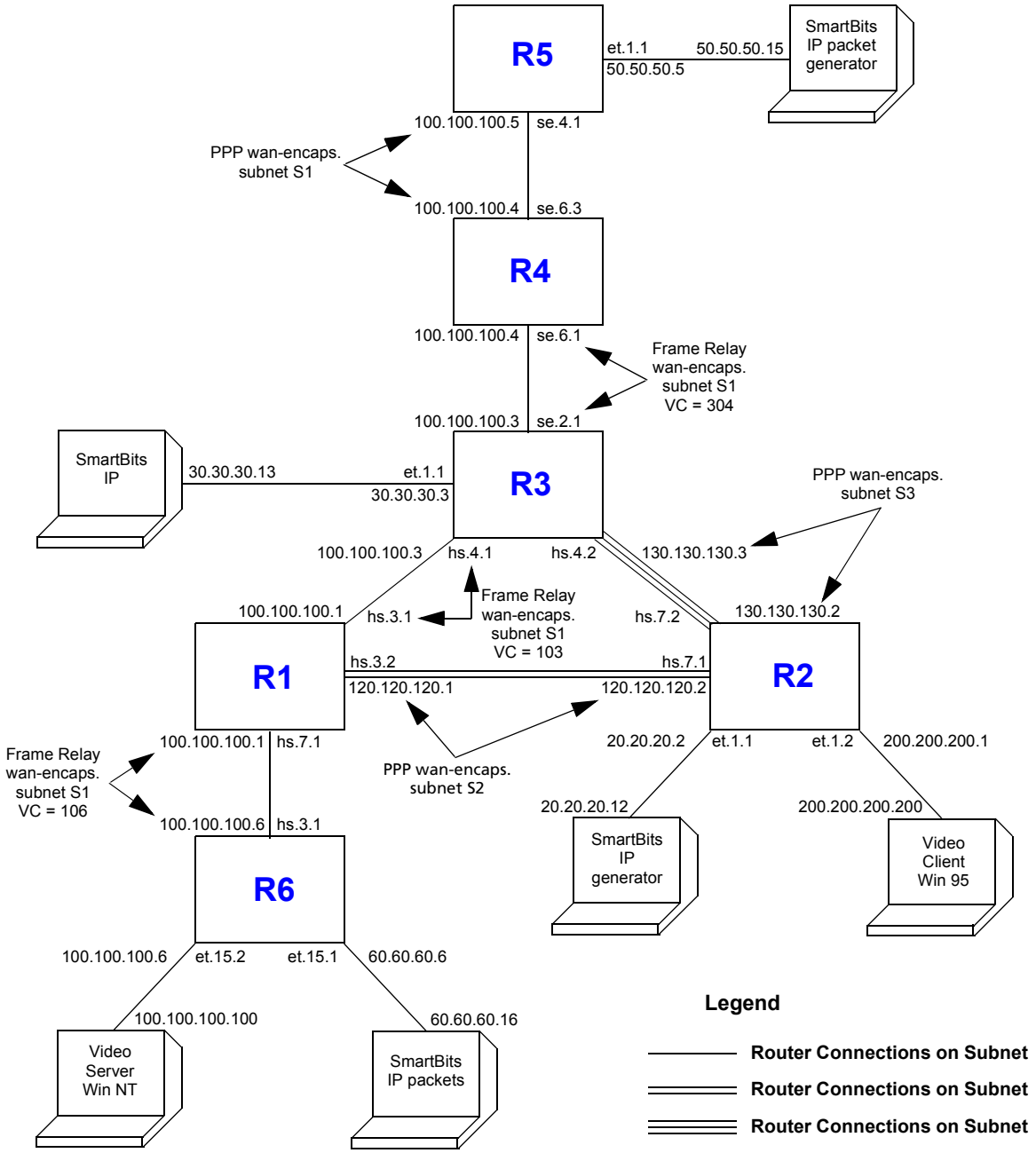

Figure 30-3 Multi-router WAN configuration

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Router R1 Configuration File

The following configuration file applies to Router R1.

```
Configuration for ROUTER R1
-----------------------------------------------------------------------
port set hs.7.1 wan-encapsulation frame-relay speed 45000000
port set hs.3.1 wan-encapsulation frame-relay speed 45000000
port set hs.3.2 wan-encapsulation ppp speed 45000000
port set et.1.* duplex full
frame-relay create vc port hs.7.1.106
frame-relay create vc port hs.3.1.103
frame-relay define service CIRforR1toR6 cir 45000000 bc 450000
frame-relay apply service CIRforR1toR6 ports hs.7.1.106
vlan create s1 id 200
vlan create s2 id 300
vlan add ports hs.3.1.103,hs.7.1.106 to s1
vlan add ports hs.3.2 to s2
interface create ip s1 address-netmask 100.100.100.1/16 vlan s1
interface create ip s2 address-netmask 120.120.120.1/16 vlan s2
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set auto-summary enable
rip start
system set name R1
```

Router R2 Configuration File

The following configuration file applies to Router R2.

```
Configuration for ROUTER R2
-----------------------------------------------------------------------
port set hs.7.1 wan-encapsulation ppp speed 45000000
port set hs.7.2 wan-encapsulation ppp speed 45000000
port set et.1.* duplex full
vlan create s2 id 300
interface create ip PPPforR2toR3 address-netmask 130.130.130.2/16 peer-address
130.130.130.3 port hs.7.2
interface create ip SBitsLAN address-netmask 20.20.20.2/16 port et.1.1
vlan add ports hs.7.1 to s2
interface create ip s2 address-netmask 120.120.120.2/16 vlan s2
interface create ip VideoClient address-netmask 200.200.200.1/16 port et.1.2
qos set ip VideoFromNT high 100.100.100.100 200.200.200.200 any any
qos set ip VideoFrom95 high 200.200.200.200 100.100.100.100 any any
rip add interface all
rip set interface all version 2
rip set auto-summary enable
rip start
system set name R2
arp add 20.20.20.12 exit-port et.1.1 mac-addr 000202:020200
```


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Router R3 Configuration File

The following configuration applies to Router 3.

```
Configuration for ROUTER R3
-----------------------------------------------------------------------
port set se.2.1 wan-encapsulation frame-relay speed 1500000
port set et.1.* duplex full
port set hs.4.1 wan-encapsulation frame-relay speed 45000000
port set hs.4.2 wan-encapsulation ppp speed 45000000
frame-relay create vc port se.2.1.304
frame-relay create vc port hs.4.1.103
vlan create s1 id 200
interface create ip SBitsLAN address-netmask 30.30.30.3/16 port et.1.1
vlan add ports hs.4.1.103,se.2.1.304 to s1
interface create ip PPPforR2toR3 address-netmask 130.130.130.3/16 peer-address
130.130.130.2 port hs.4.2
interface create ip s1 address-netmask 100.100.100.3/16 vlan s1
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set broadcast-state always
rip set auto-summary enable
rip start
system set name R3
arp add 30.30.30.13 exit-port et.1.1 mac-addr 000303:030300
```

Router R4 Configuration File

The following configuration file applies to Router R4.

```
Configuration for ROUTER R4
-----------------------------------------------------------------------
port set se.6.1 wan-encapsulation frame-relay speed 1500000
port set se.6.3 wan-encapsulation ppp speed 1500000
port set et.1.* duplex full
frame-relay create vc port se.6.1.304
vlan create s1 id 200
vlan add ports se.6.1.304,se.6.3 to s1
interface create ip s1 address-netmask 100.100.100.4/16 vlan s1
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set broadcast-state always
rip set auto-summary enable
rip start
system set name R4
```


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Router R5 Configuration File

The following configuration file applies to Router R5.

```
!Configuration for ROUTER R5
port set se.4.1 wan-encapsulation ppp speed 1500000
port set et.1.* duplex full
vlan create s1 id 200
interface create ip lan1 address-netmask 50.50.50.5/16 port et.1.1
vlan add ports se.4.1 to s1
interface create ip s1 address-netmask 100.100.100.5/16 vlan s1
rip add interface all
rip set auto-summary enable
rip set interface all version 2
rip start
system set name R5
arp add 50.50.50.15 mac-addr 000505:050500 exit-port et.1.1
```

Router R6 Configuration File

The following configuration file applies to Router R6.

```
!Configuration for ROUTER R6
port set et.15.* duplex full
port set hs.3.1 wan-encapsulation frame-relay speed 45000000
frame-relay create vc port hs.3.1.106
frame-relay define service CIRforR1toR6 cir 45000000 bc 450000
frame-relay apply service CIRforR1toR6 ports hs.3.1.106
vlan create BridgeforR1toR6 port-based id 106
interface create ip FRforR1toR6 address-netmask 100.100.100.6/16 vlan BridgeforR1toR6
interface create ip lan1 address-netmask 60.60.60.6/16 port et.15.1
vlan add ports hs.3.1.106 to BridgeforR1toR6
vlan add ports et.15.2 to BridgeforR1toR6
qos set ip VideoFromNT high 100.100.100.100 200.200.200.200 any any
qos set ip VideoFrom95 high 200.200.200.200 100.100.100.100 any any
rip add interface all
rip set interface all version 2
rip set auto-summary enable
rip start
system set name R6
arp add 60.60.60.16 mac-addr 000606:060600 exit-port et.15.1
```


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30.16 CHANNELIZED T1, E1 AND T3 SERVICES OVERVIEW

The Channelized T1 and E1 services are full duplex TDM services that provide aggregation for low speed services that have different bandwidth requirements, such as voice, data, video, and so on, using one or more 64 kbps (DS0) channels. The full (unframed) T1 and channelized T3 services, on the other hand, provide a cost effective Multi-Tenant-Unit/Multi-Dwelling-Unit (MTU/MDU) aggregation solution into a Metropolitan Service Provider (MSP) hub.

The T1 service is the entire end-to-end service, and runs over the DS1 interface. Similarly, T3 is the service and DS3 the interface. The number of channels, and the capacity of each interface is listed in Table 30-1.

Table 30-1 Channelized DS1, E1 and DS3 Interfaces

Interface	Number of Channels	Capacity (Mbps)	Line Speed (Mbps)
DS1	24 DS0 channels	1.536	1.544
E1	32	1.920/ 1.984	2.048
DS3	28 DS1 lines	43.008	44.736

30.16.1 T1 and E1 WAN Interface Cards

Each T1 and E1 WAN Interface Card (WIC) has two ports, and an internal CSU/DSU. The T1 WIC has two RJ-48c connectors, and the E1 WIC has two 120 Ohm RJ-45 connectors. Two T1 or E1 WICs, or a T1 and E1 WIC, can be installed in a Multi-Rate WAN module, giving a total of four ports. Each T1/E1 WIC has three modes of operation, depending on the service requirements:

- Channelized T1 and E1, for services that require multiples of 64 kbps bandwidth. A single channel is used for each service — for example, T1 can have 24 DS0 channels.
- Fractional T1 and E1, for services that require multiples of the 64 kbps channels. For example, T1 services may be high-speed data on a 512 kbps channel, plus 16 low speed data and voice channels at 64 kbps.
- Full (unstructured) T1 and E1, when a service requires the full T1 or E1 bandwidth. For example, point-to-point data transmission.

Framing and line coding schemes are employed to ensure the reliable transmission of the data; the schemes used depend on the interface, as shown in Table 30-2.

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Table 30-2 T1 and E1 Framing and Line Coding Schemes

Interface	Framing	Line Coding
T1	• Extended Superframe Format (ESF) • Superframe — D4 Framing (SF) Japanese variants of these formats are also supported: • sf-japan • esf-japan	• Bipolar 8 zero substitution (B8ZS) • Alternate Mark Inversion (AMI)
E1	• CRC4, cyclic redundancy check 4 • NOCRC4, International (*Si*) Bits used	• High-density bipolar 3 (HDB3) • Alternate Mark Inversion (AMI)

Warning Hot swapping WICs is not yet supported.

30.16.2 Channelized T3 Service Interface Module

The Channelized T3 (CT3) service interface module on the RS 32000 and RS 38000 comprises four ports, with each port connection having a separate BNC connector Transmit/Receive pair. The module has an internal DSU, and each CT3 port has an associated RJ-48c T1 test port. The CT3 service interface module for the RS 8000 and 8600 has two ports, but has no test ports.

A total of 28 DS1 channels are available for the serial transmission of data. Each DS1 channel can be configured to use a portion of the DS1 bandwidth or the entire DS1 bandwidth for data transmission. Bandwidth for each DS1 channel can be configured for n x 56 kbps or n x 64 kbps (where n is 1 to 24). The unused portion of the T1 bandwidth, when not running at full T1 speed, is filled with idle-channel data.

The CT3 service module provides bandwidth aggregation functionality via the standards based Multilink PPP.

Framing and line coding schemes are employed to ensure the reliable transmission of the data; the schemes used depend on the interface, as shown in Table 30-3.

Table 30-3 Channelized DS3 Framing and Line Coding Schemes

Interface	Framing	Line Coding
DS3	• C-bit Framing • M23 Framing	• Bipolar 3 zero substitution (B3ZS)

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DS1 Test Port Control for the RS 32000 and RS 38000 CT3

Each Channelized T3 port has an associated T1 test port, which provides access to any of the DS1 channels within a Channelized T3 (see Figure 30-4). You can configure the test port in either monitor or break-out mode.

- In *monitor mode*, you may connect an external analyzer to a test port to allow transparent monitoring of data on a given selected DS1 channel.
- In *break-out mode*, you can remove the selected DS1 channel from service, which allows you to connect external test equipment to verify the operation of the DS1 channel. The break-out mode is mainly intended for support of external BERT equipment (see Section 30.16.4, *"Bit Error Rate Testing"*).

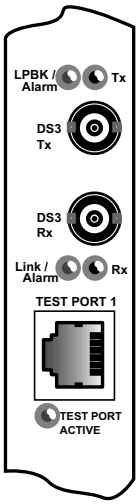

Figure 30-4 T3 port with T1 test port

Also, a separate DS1 test port connection is provided per T3 interface for the monitoring or break-out testing of an individual DS1 channel within a channelized T3 group. The DS1 test port connections are provided by RJ-48c connectors. The test port connections are not provided on the clear-channel modules.

30.16.3 Configuring Channelized T1, E1 and T3 Interfaces

This section discusses the basics of the Channelized T1, E1 and T3 interfaces. It provides the following examples for configuring these interfaces and basic interface function:

- Configuring a Channelized T1 interface
- Configuring an Channelized E1 interface
- Configuring a Channelized T3 interface
- Creating a MLP bundle
- Creating a VLAN
- Configuring T1 lines in Channelized T3

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Configuring a Channelized T1 Interface

The following commands are an example of configuring a basic Channelized T1 interface.

```
rs(config)# port set t1.2.(1-4) framing esf fdl ansi lbo -7.5db
rs(config)# port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp
```

For the Channelized T1 interface example:

- **port set t1.2.(1-4):1** - Configures the following parameters for ports 1 through 4.
- **framing esf** - Sets the framing type to Extended Super Frame.
- **fdl ansi** - Sets the Facilities Data Link (data channel) to ANSI.
- **lbo -7.5db** - Sets the line loss to -7.5 db.
- **timeslots 1-24** - Sets the range of time slots to select in a frame from 1 to 24.
- **wan-encapsulation ppp** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **timeslots**.

Configuring a Channelized E1 Interface

The following commands are an example of configuring a basic Channelized E1 interface.

```
rs(config)# port set e1.2.(1-4) framing crc4 impedance 75ohm
rs(config)# port set e1.2.(1-4):1 timeslots 1-31 ts16 wan-encapsulation ppp
```

For the Channelized E1 interface example:

- **port set e1.3.(1-4):1** - Configures the following parameters for ports 1 through 4.
- **framing crc4** - Sets the framing type to Cyclic Redundancy Check 4.
- **impedance 75ohm** - Sets the impedance of the line to 75 ohm.
- **timeslots 1-31** - Sets the range of time slots to select in a frame from 1 to 31.
- **ts16** - Sets timeslot 16 to be used for data. If timeslot 16 is used with other timeslots, **ts16** must be specified on the same line as the **timeslots**.
- **wan-encapsulation ppp** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **timeslots** and **ts16**.

Configuring Channelized T3 Interfaces

The following commands are an example of configuring a basic Channelized T3 interface.

```
rs(config)# port set t3.4.1 lbo -7.5db
```

For the Channelized T3 interface example:

- **port set t3.4.1** - Configures the following parameter for the Channelized T3 interface on port 1.
- **lbo -7.5db** - Sets the Channelized T3 line loss to -7.5 db.

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Basic Channelized T1, E1 and T3 Interface Functions

MLPs

Multilink PPP (MLPs) is a set of multiple physical links grouped into a logical pipe called an MLP bundle. Channelized T1 and E1 MLPs can be used for splitting, recombining and sequencing datagrams. Create a MLP with Channelized T1 lines using the following commands.

```
rs(config)# ppp create-mlp mp.1 slot 2
rs(config)# ppp add-to-mlp mp.1 port t1.2.(1-4)
```

For the MLP example:

- **ppp create-mlp mp.1** - Creates a multilink PPP bundle named mp.1.
- **slot 2** - Designates the MLP slot number.
- **ppp add-to-mlp mp.1** - Adds ports to a previously defined bundle mp.1.
- **port t1.2.(1-4)** - Designates the ports to be added to the bundle.

Note MLP bundles cannot be created across multiple line cards.

VLANs

Channelized T1 or E1 VLANs can be created and used for bridging to MSP's. Create a VLAN using the following command.

```
rs(config)# vlan create vlan1 port-based id 100
```

For the VLAN example:

- **vlan create vlan1 port-based** - Creates a port-based VLAN.
- **id 100** - Names the VLAN.

T1 Lines

T1 lines (channels) can be created within the Channelized T3 interface. Channelized T3 interfaces with T1 lines can be used for multimedia transmission within one Channelized T3 interface. Create T1 lines for a Channelized T3 interface using the following commands.

```
rs(config)# port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
```

For the T1 lines example:

- **port set t3.4.1:(1-28)** - Configures the following parameters for all 28 T1 lines of the Channelized T3 interface on port 1.
- **timeslots 1-24** - Sets the range of time slots, on the T1 lines to select in a frame, from 1 to 24.
- **wan-encapsulation ppp** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **timeslots**.

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Configuring Frame Relay over Channelized T1, E1 and T3 Interfaces

Configure Frame Relay over a Channelized T1, E1 or T3 interface as follows:

```
port set t1.4.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set e1.5.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set t3.6.1:1 timeslots 1-4 wan-encapsulation frame-relay
frame-relay create vc port t1.4.1:1.103
frame-relay create vc port e1.5.1:1.105
frame-relay create vc port t3.6.1:1.104
frame-relay define service t1service cir 64000 bc 128000
frame-relay apply service t1service ports t1.4.1:1.103
frame-relay define service e1service cir 64000 bc 128000
frame-relay apply service e1service ports e1.5.1:1.104
frame-relay define service t3service cir 1544000 bc 2048000
frame-relay apply service t3service ports t3.6.1:1.105
interface create ip fr1 address-netmask 10.10.30.1/24 port t1.4.1:1 up
interface create ip fr2 address-netmask 10.10.40.1/24 port e1.5.1:1 up
interface create ip fr3 address-netmask 10.10.50.1/24 port t3.6.1:1 up
```

30.16.4 Bit Error Rate Testing

The Bit Error Rate Testing (BERT) functionality allows you to test a DS1 or E1 interface, or DS1 line within a DS3, for cable and signal problems while installed in a field environment. BERT consists of sending a data pattern for a configurable amount of time while monitoring the received data pattern. Since BERT expects to receive the same pattern that is being transmitted, you can either configure the line in a loopback configuration or the remote-end can be set up to send the same pattern; setting up a loopback prior to invoking BERT on a given DS1 or E1 connection is the most common setup. BERT keeps track of the bit receive count versus the number of receive bit errors over time, and the result is the Bit Error Rate.

The patterns available for BERT are selectable from a standard set of both pseudo-random and repetitive patterns (see the parameters for the **`port bert`** command).

BERT can only be performed on a single physical or logical port. To perform a BERT test on a single port in a Multilink bundle, the port must first be removed from the bundle.

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Example: Configuring Loopbacks and Using BERT Testing on a DS1 Interface

This example shows the use of BERT to test a structured DS1 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 speed-56 wan-encapsulation ppp
save active
exit
port loopback t1.2.1 remote-line-fdl-ansi
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t1.2.1 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t1.2.1 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t1.2.1 all
!-------------------------------------------------------------------------
! To stop the test before the one hour interval expires.
!-------------------------------------------------------------------------
port bert t1.2.1 stop
```


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Example: Configuring Loopbacks and Using BERT Testing on a DS3 Interface

This example shows the use of BERT to do an internal test of the 15th DS1 line of a DS3 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t3.2.1:15 framing esf
save active
exit
port loopback t3.2.1:15 remote-line-fdl-ansi
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t3.2.1:15 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t3.2.1:15 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t3.2.1:15 all
```


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Example: Configuring Loopbacks and Using BERT Testing on a Channelized E1 Interface

This example shows the use of BERT to test a structured E1 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set e1.3.1 framing nocrc4 international-bits 0
port set e1.3.1:1 timeslots 1-31 ts16 wan-encapsulation ppp
save active
exit
port loopback e1.3.1 network-line
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert e1.3.1 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
! To start the test.
!-------------------------------------------------------------------------
port bert e1.3.1 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info e1.3.1 all
!-------------------------------------------------------------------------
! To stop the test before the one hour interval expires.
!-------------------------------------------------------------------------
port bert e1.3.1 stop
```

30.16.5 Configuring a Test using External Test Equipment

If you want to do a test using external test equipment, then enter the **`port testport`** *<port-list>* **`monitor`** command before any **`port set`** commands.

Using the BERT test on the DS3 interface as an example, the command sequence would be:

```
enable
config
port testport t3.2.1:15 monitor
port set t3.2.1:15 framing esf
save active
exit
port loopback t3.2.1:15 remote-line-fdl-ansi
port bert t3.2.1:15 pattern 2^20-QRSS interval 60
port bert t3.2.1:15 start
port show serial-link-info t3.2.1:15 all
```


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30.17 CLEAR CHANNEL T3 AND E3 SERVICES OVERVIEW

Clear Channel T3 and E3 utilizes the full DS3 bandwidth for data transmission as shown in Table 30-4.

Table 30-4 Clear Channel T3 and E3 Interface Rates

Interface	Capacity (Mbps)
T3	44.736
E3	34.368

30.17.1 Clear Channel T3 and E3 Service Interface Module

Each Clear Channel T3 and E3 WAN Interface Card (WIC) has one port, and an internal CSU/DSU. The WICs have a BNC connector Transmit/Receive pair. Two T3 or E3 WICs, or a T3 and an E3 WIC, can be installed in a Multi-Rate WAN module, giving a total of two ports.

Framing and line coding schemes are employed to ensure the reliable transmission of the data; the schemes used depend on the interface, as shown in Table 30-5.

Table 30-5 Clear Channel T3 and E3 Framing and Line Coding

Interface	Framing	Line Coding
T3	• C-bit • M23	• Bipolar 3 zero substitution (B3ZS)
E3	• G751 Framing • G832 Framing	• High-density bipolar 3 (HDB3)

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30.18 SCENARIOS FOR DEPLOYING CHANNELIZED T1, E1 AND T3

This section describes some scenarios for deploying Channelized T1, E1 and T3. There are nine scenarios, which cover the deployment for:

- Bridged MSP MTU/MDU aggregation (see Section 30.18.1)
- Routed inter-office connections through an Internet Service Provider (ISP)
  - With only Channelized T1 on the RS 8000 and RS 8600 (see Section 30.18.2)
  - With Channelized T1 and T3 on the RS 8000 and RS 8600 (see Section 30.18.3)
- Routed Metropolitan Backbone
  - With only Channelized T1 on the RS 8000 and RS 8600 (see Section 30.18.4)
  - With Channelized T1 and T3 on the RS 8000 and RS 8600 (see Section 30.18.5)
- Routed inter-office connections through an Internet Service Provider (ISP) with Channelized E1 (see Section 30.18.6)
- Routed Metropolitan Backbone with Channelized E1 (see Section 30.19.2)
- Transatlantic connection using Channelized T1 and E1 (see Section 30.18.7)
- Frame Relay over Channelized T1 (see Section 30.18.8)

30.18.1 Scenario 1: Bridged MSP MTU/MDU Aggregation

In this scenario, a company has several sites that need to be connected. An MSP provides a Channelized T3 connection on their RS 32000. Each site has several LANs interconnected through an RS 3000, which also provides four T1 lines to the MSP. These T1 lines are grouped into a Multilink PPP bundle, so up to seven sites can be interconnected using a single Channelized T3 line. Note that in this scenario, each MTU/MDU has four T1 lines. In practice, an MSP may start with one T1 and grow as their business grows. There is also a cost consideration in that once the MSP uses a certain number of T1 lines it may become more economical to use T3 lines.

Note that if you require redundancy, backup T3 lines could be provided on other RS 32000s.

Figure 30-5 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the MSP, head office (hqsite), and the remote site, rsite2. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 32000	1 CT3 module with 4 T3 ports.
Each RS 3000	1 Multi-Rate WAN module with 2 T1 WICs.

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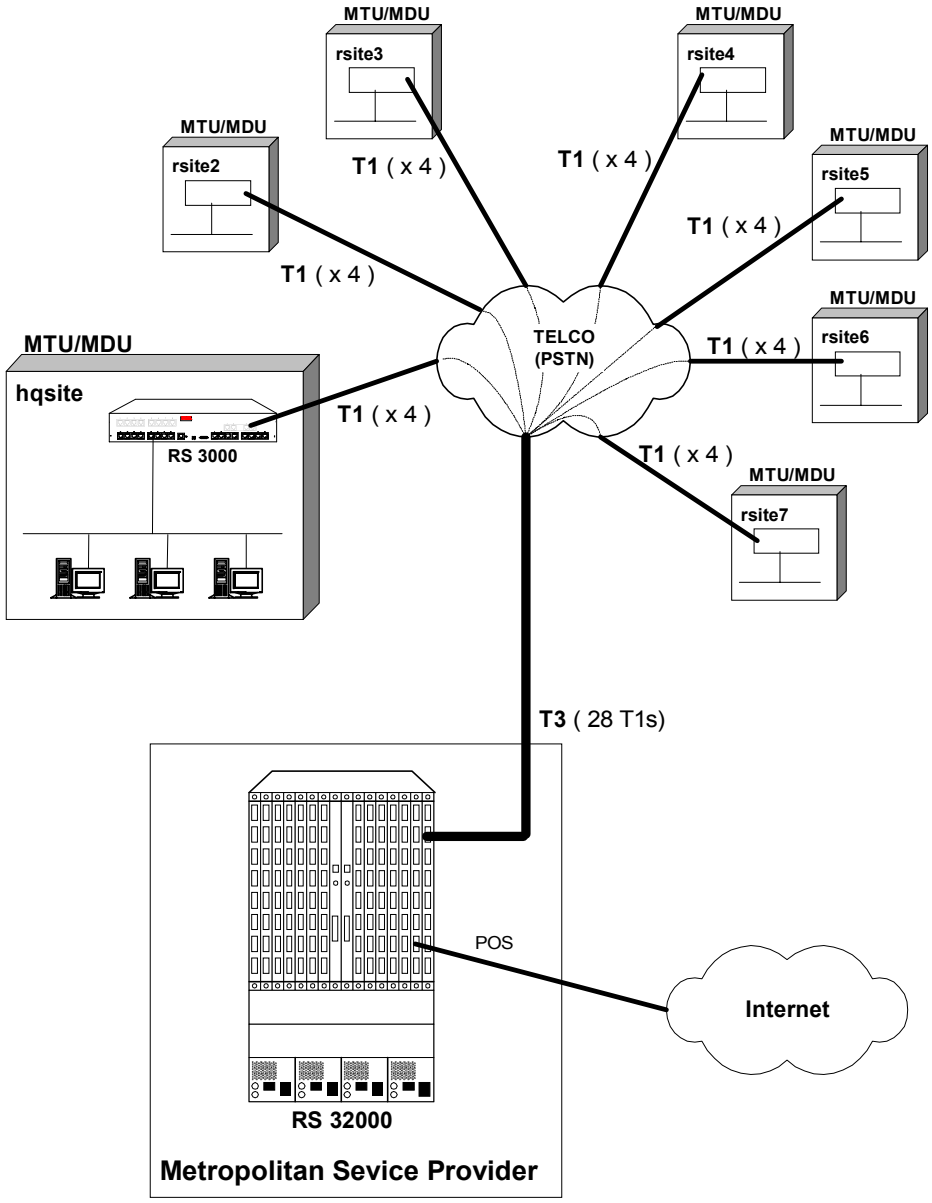

Figure 30-5 Bridged MSP MTU/MDU Aggregation

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Metropolitan Service Provider RS 32000 Configuration

The following configuration applies to the RS 32000 router at the Metropolitan Service Provider.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)
!-----------------------------------------------------------------------------
!Configure VLAN and bridging link to each site:
!-----------------------------------------------------------------------------
vlan create vlan1 port-based id 100
vlan add ports mp.1 to vlan1
interface create ip to_vlan1 address-netmask 120.210.1.1/24 vlan vlan1 up
vlan create vlan2 port-based id 200
vlan add ports mp.2 to vlan2
interface create ip to_vlan2 address-netmask 120.210.2.1/24 vlan vlan2 up
vlan create vlan3 port-based id 300
vlan add ports mp.3 to vlan3
interface create ip to_vlan3 address-netmask 120.210.3.1/24 vlan vlan3 up
vlan create vlan4 port-based id 400
vlan add ports mp.4 to vlan4
interface create ip to_vlan4 address-netmask 120.210.4.1/24 vlan vlan4 up
vlan create vlan5 port-based id 500
vlan add ports mp.5 to vlan5
interface create ip to_vlan5 address-netmask 120.210.5.1/24 vlan vlan5 up
vlan create vlan6 port-based id 600
vlan add ports mp.6 to vlan6
interface create ip to_vlan6 address-netmask 120.210.6.1/24 vlan vlan6 up
vlan create vlan7 port-based id 700
vlan add ports mp.7 to vlan7
interface create ip to_vlan7 address-netmask 120.210.7.1/24 vlan vlan7 up
```


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hqsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1

!-------------------------------------------------------------------------
!Configure VLAN and bridging for link to MSP:
!-------------------------------------------------------------------------
vlan create vlan1port-based id 100
vlan add ports mp.1 to vlan1
interface create ip vlan_to_msp address-netmask 120.210.1.2/24 vlan vlan1 up
```

rsite2 RS 3000 Configuration

The following configuration applies to router RS 3000 at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the SP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.2 slot 2
ppp add-to-mlp mp.2 port t1.2.(1-4):1
!-------------------------------------------------------------------------
!Configure VLAN and bridging for link to MSP:
!-------------------------------------------------------------------------
vlan create vlan2 port-based id 200
vlan add ports mp.2 to vlan2
interface create ip vlan_to_msp address-netmask 120.210.2.2/24 vlan vlan2 up
```


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30.18.2 Scenario 2: Routed Inter-Office Connections with Only T1 on RS 8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. To access the shared data or the Internet, all sites have four T1 lines grouped into a Multilink PPP bundle to connect to the ISP, and so are just one hop away.

The company also has significant inter-office communications. All remote sites frequently communicate with head office, so a T1 line is provided to each remote site. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by a T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 32000, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 30-6 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 32000	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 3000 (rsite4)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 T1 WICs.

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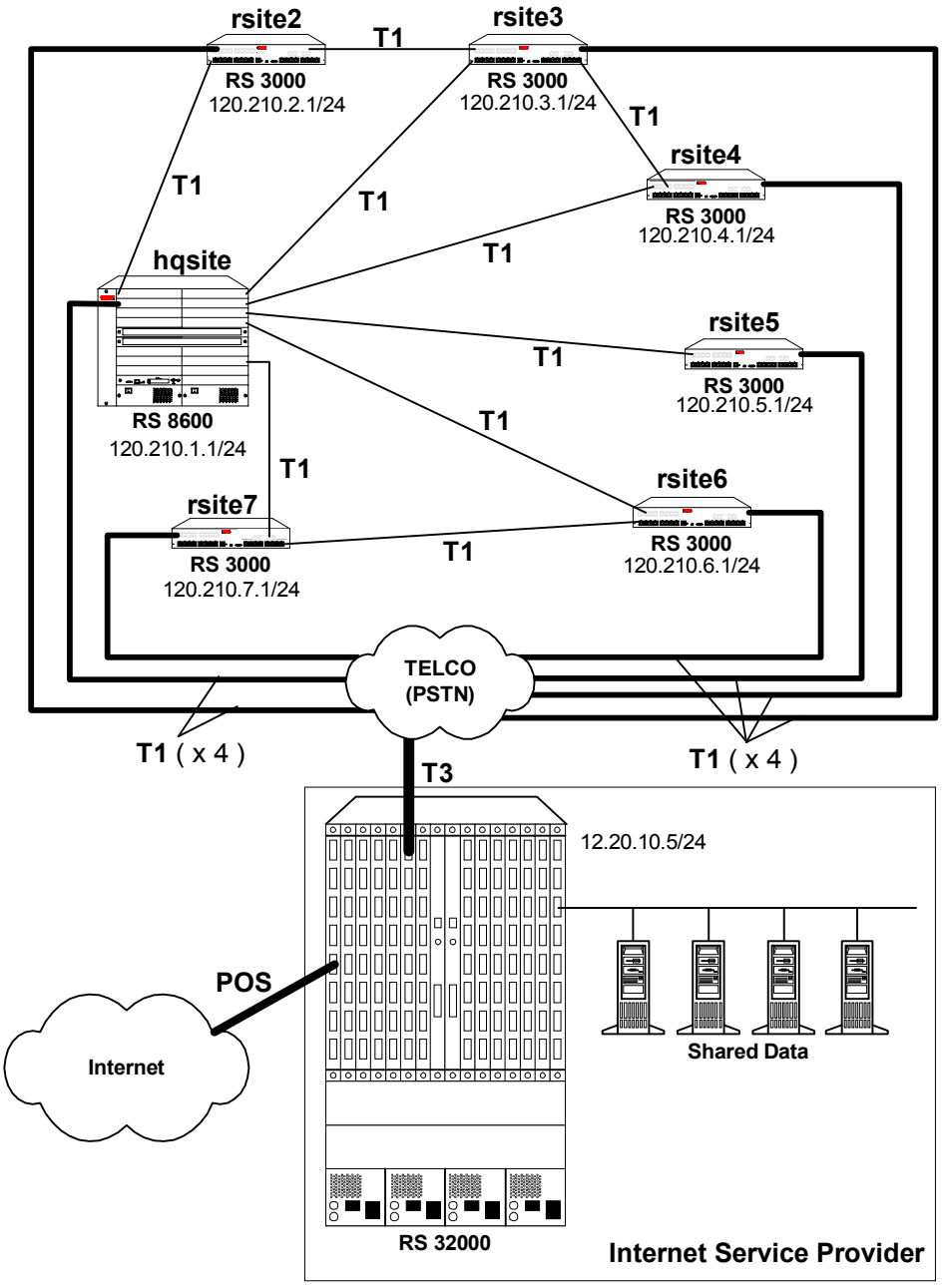

Figure 30-6 Routed Inter-Office Connections with Only T1 on RS 8x00

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ISP RS 32000 Configuration

The following configuration applies to the RS 32000 router at the ISP.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_hqsite address-netmask 120.210.1.1/24 port mp.1 up
interface create ip to_rsite2 address-netmask 120.210.2.1/24 port mp.2 up
interface create ip to_rsite3 address-netmask 120.210.3.1/24 port mp.3 up
interface create ip to_rsite4 address-netmask 120.210.4.1/24 port mp.4 up
interface create ip to_rsite5 address-netmask 120.210.5.1/24 port mp.5 up
interface create ip to_rsite6 address-netmask 120.210.6.1/24 port mp.6 up
interface create ip to_rsite7 address-netmask 120.210.7.1/24 port mp.7 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.1.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the remote sites:
!-------------------------------------------------------------------------
port set t1.3.(1-4) framing esf lbo -7.5db
port set t1.3.(1-4):1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.12.2/24 port t1.3.1 up
interface create ip to_rsite3 address-netmask 120.210.13.3/24 port t1.3.2 up
interface create ip to_rsite4 address-netmask 120.210.14.4/24 port t1.3.3 up
interface create ip to_rsite5 address-netmask 120.210.15.5/24 port t1.3.4 up
port set t1.4.(1-2) framing esf lbo -7.5db
port set t1.4.(1-2):1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite6 address-netmask 120.210.16.6/24 port t1.4.1 up
interface create ip to_rsite7 address-netmask 120.210.17.7/24 port t1.4.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.12.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```


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rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.13.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.4/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```


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30.18.3 Scenario 3: Routed Inter-Office Connections with T1 and T3 on RS 8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. All remote sites have four T1 lines grouped into a Multilink PPP bundle to connect to the RS 8600 at the head office. Where significant traffic between two remote sites exists, they are also connected by a T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 32000, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 30-7 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 32000	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	1 CT3 module (with 2 T3 ports). 6 Multi-Rate WAN modules with 12 T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite4)	1 Multi-Rate WAN module with 2 T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 T1 WICs.

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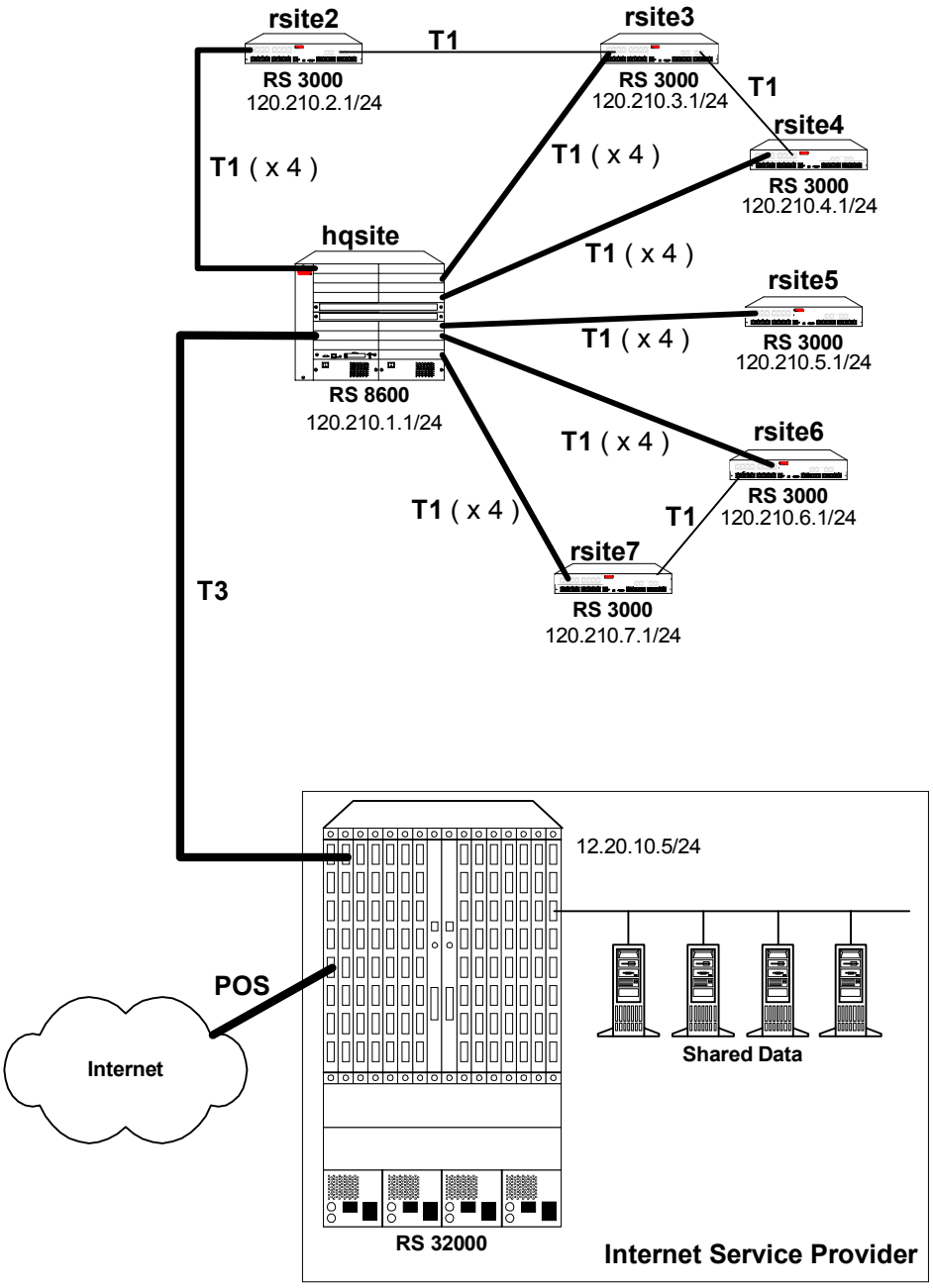

Figure 30-7 Routed Inter-Office Connections with T1 and T3 on RS 8x00

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ISP RS 32000 Configuration

The following configuration applies to the RS 32000 router at the ISP.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite2 address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite3 address-netmask 120.210.13.1/24 port mp.3 up
interface create ip to_rsite4 address-netmask 120.210.14.1/24 port mp.4 up
interface create ip to_rsite5 address-netmask 120.210.15.1/24 port mp.5 up
interface create ip to_rsite6 address-netmask 120.210.16.1/24 port mp.6 up
interface create ip to_rsite7 address-netmask 120.210.17.1/24 port mp.7 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!--------------------------------------------------------------------------
!Configuration for the RS 8600 Channelized T3 interface
!--------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!--------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!--------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!--------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!--------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_isp1 address-netmask 12.20.11.2/24 port mp.1 up
interface create ip to_isp2 address-netmask 12.20.12.2/24 port mp.2 up
interface create ip to_isp3 address-netmask 12.20.13.2/24 port mp.3 up
interface create ip to_isp4 address-netmask 12.20.14.2/24 port mp.4 up
interface create ip to_isp5 address-netmask 12.20.15.2/24 port mp.5 up
interface create ip to_isp6 address-netmask 12.20.16.2/24 port mp.6 up
interface create ip to_isp7 address-netmask 12.20.17.2/24 port mp.7 up
!--------------------------------------------------------------------------
!Configure RIP:
!--------------------------------------------------------------------------
rip add interface to_isp1
rip add interface to_isp2
rip add interface to_isp3
rip add interface to_sip4
rip add interface to_isp5
rip add interface to_isp6
rip add interface to_isp7
rip start
```


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The following configuration applies to the T1 interfaces on the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.5.(1-4) framing esf lbo -7.5db
port set t1.5.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.6.(1-4) framing esf lbo -7.5db
port set t1.6.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.7.(1-4) framing esf lbo -7.5db
port set t1.7.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.8.(1-4) framing esf lbo -7.5db
port set t1.8.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.9.(1-4) framing esf lbo -7.5db
port set t1.9.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.10.(1-4) framing esf lbo -7.5db
port set t1.10.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.9 slot 5
ppp add-to-mlp mp.9 port t1.5.(1-4):1
interface create ip to_rsite2 address-netmask 120.210.2.1/24 port mp.9 up
ppp create-mlp mp.10 slot 6
ppp add-to-mlp mp.10 port t1.6.(1-4):1
interface create ip to_rsite3 address-netmask 120.210.3.1/24 port mp.10 up
ppp create-mlp mp.11 slot 7
ppp add-to-mlp mp.11 port t1.7.(1-4):1
interface create ip to_rsite4 address-netmask 120.210.4.1/24 port mp.11 up
ppp create-mlp mp.12 slot 8
ppp add-to-mlp mp.12 port t1.8.(1-4):1
interface create ip to_rsite5 address-netmask 120.210.5.1/24 port mp.12 up
ppp create-mlp mp.13 slot 9
ppp add-to-mlp mp.13 port t1.9.(1-4):1
interface create ip to_rsite6 address-netmask 120.210.6.1/24 port mp.13 up
ppp create-mlp mp.14 slot 10
ppp add-to-mlp mp.14 port t1.10.(1-4):1
interface create ip to_rsite7 address-netmask 120.210.7.1/24 port mp.14 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```


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rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite4:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.3/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```


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30.18.4 Scenario 4: Routed Metropolitan Backbone with Only T1 on RS 8x00

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 32000 connected by Packet Over SONET (POS) links.

An MSP provides a Channelized T3 service using an RS 32000. A company has two sites that connect to this service:

- The head office (hqsite) connects using Multilink PPP bundled T1 lines from an RS 8600.
- The remote site, rsite, connects to the MSP using a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the head office.

Internet Service Provider A uses a POS link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using Multilink PPP bundled T1 lines from an RS 8000.

Figure 30-8 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 32000 (MSP)	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 32000 (ISP B)	1 CT3 module (with 4 T3 ports).
RS 8000 (CP)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 8000 (ASP)	2 Multi-Rate WAN modules with 4 T1 WICs.

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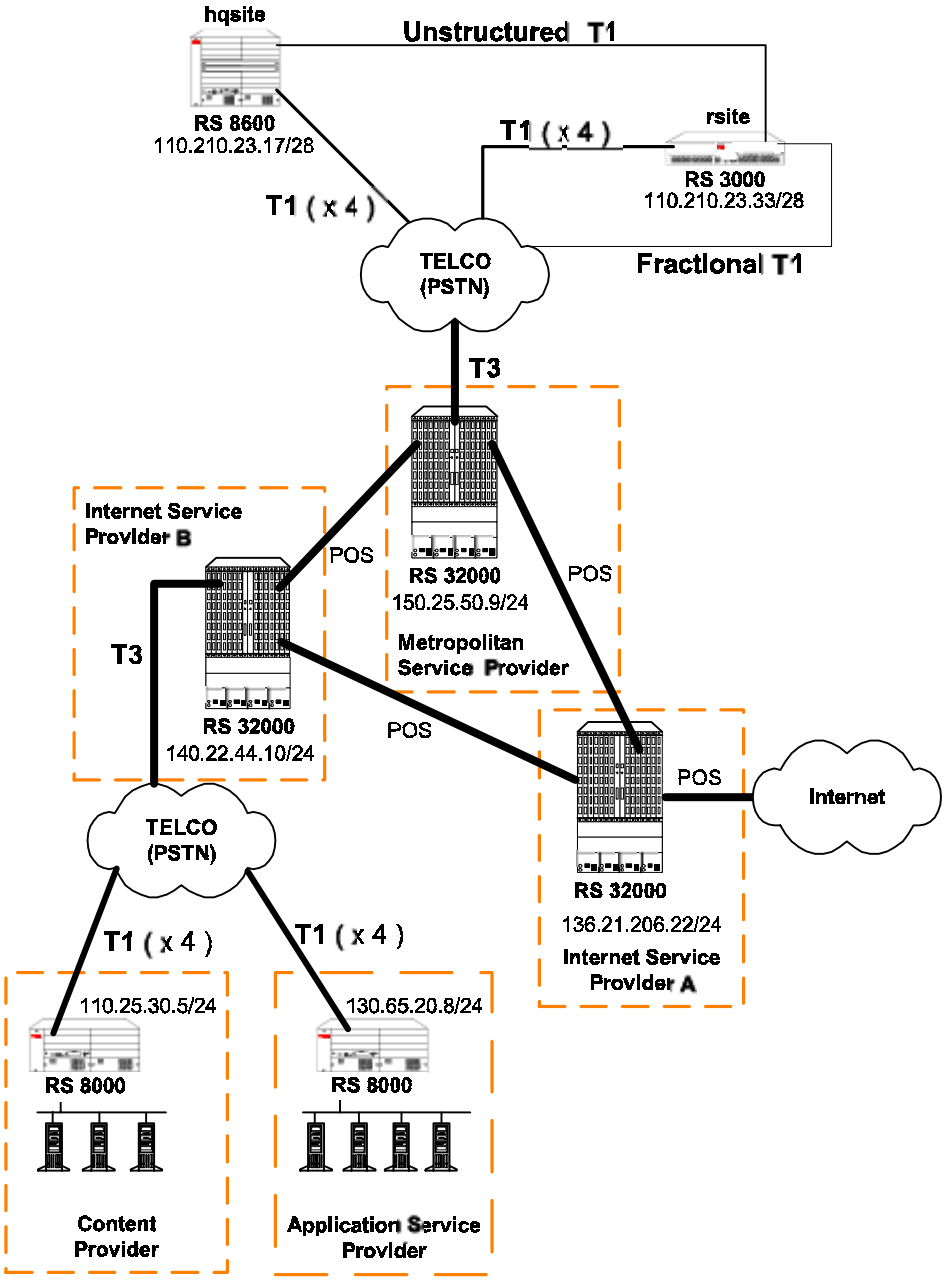

Figure 30-8 Routed Metropolitan Backbone with Only T1 on RS 8x00

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Metropolitan Service Provider RS 32000 Configuration

The following configuration applies to the RS 32000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.23.19/28 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.23.49/28 port mp.2up
interface create ip to_rsite_ft1 address-netmask 120.210.23.65/28 port t3.4.1:13
up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip start
```


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hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 120.210.23.18/28 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite address-netmask 120.210.23.35/28 port t1.3.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp
rip add interface to_rsite
rip start
```


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rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp_mppp address-netmask 120.210.23.50/28 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the MSP:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_msp_ft1 address-netmask 120.210.23.66/28 port t1.3.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.23.34/28 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp_mppp
rip add interface to_msp_ft1
rip add interface to_hqsite
rip start
```


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Internet Service Provider B RS 32000 Configuration

The following configuration applies to the RS 32000 router at Internet Service Provider B.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-20) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-8)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(13-20)

interface create ip to_cp address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_asp address-netmask 130.65.20.9/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_cp
rip add interface to_asp
rip start
```

Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp
ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 110.25.30.5/24 port mp.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp
rip start
```


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Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 130.65.20.8/24 port mp.1 up

!-------------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------------
rip add interface to_msp
rip start
```


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30.18.5 Scenario 5: Routed Metropolitan Backbone with T1 and T3 on RS 8x00

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 32000 connected by Packet Over SONET (POS) links.

An MSP provides a Channelized T3 service using an RS 32000. A company has two sites that connect to this service:

- The head office (hqsite) connects using a T3 line from an RS 8600.
- The remote site, rsite, connects to the RS 8600 at head office using four T1 lines bundled with Multilink PPP, a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the RS 8600.

Internet Service Provider A uses a POS link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using T3 lines from an RS 8000.

Figure 30-9 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 32000 (MSP)	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	1 CT3 module (with 2 T3 ports). 2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 32000 (ISP B)	1 CT3 module (with 4 T3 ports).
RS 8000 (CP)	1 CT3 module (with 2 T3 ports).
RS 8000 (ASP)	1 CT3 module (with 2 T3 ports).

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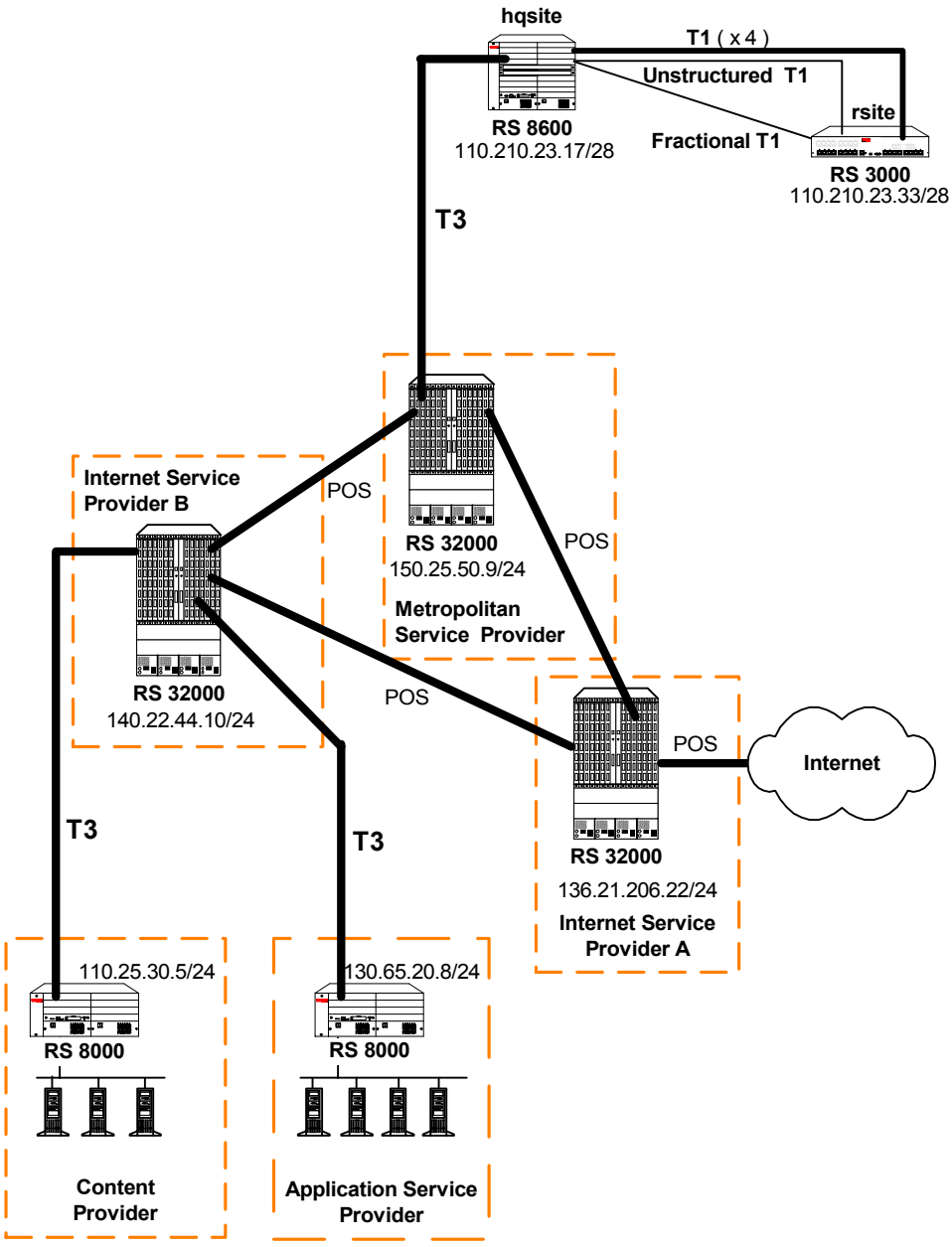

Figure 30-9 Routed Metropolitan Backbone with T1 and T3 on RS 8x00

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Metropolitan Service Provider RS 32000 Configuration

The following configuration applies to the RS 32000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite_ft1 address-netmask 120.210.13.1/24 port t3.4.1:13 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip start
```


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hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!--------------------------------------------------------------------------
!Configuration for the RS 8600 Channelized T3 interface
!--------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!--------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!--------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
!--------------------------------------------------------------------------
!Configure a multilink PPP bundle containing 4 consecutive T1 lines
!--------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)

interface create ip to_msp address-netmask 120.210.11.2/24 port mp.1 up
!--------------------------------------------------------------------------
!Configure RIP:
!--------------------------------------------------------------------------
rip add interface to_msp
rip start
```


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The following configuration applies to the T1 interfaces on the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the rsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_rsite_mppp address-netmask 120.210.4.1/24 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite_fullt1 address-netmask 120.210.1.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.2:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.2:3 timeslots 19 wan-encapsulation ppp
port set t1.3.2:4 timeslots 20 wan-encapsulation ppp
port set t1.3.2:5 timeslots 21 wan-encapsulation ppp
port set t1.3.2:6 timeslots 22 wan-encapsulation ppp
port set t1.3.2:7 timeslots 23 wan-encapsulation ppp
port set t1.3.2:8 timeslots 24 wan-encapsulation ppp
interface create ip to_rsite_fract1 address-netmask 120.210.24.1/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite_mppp
rip add interface to_rsite_fullt1
rip add interface to_rsite_fract1
rip start
```


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rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite_mppp address-netmask 120.210.4.2/24 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_hqsite_fract1 address-netmask 120.210.24.2/24 port t1.3.1
up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite_fullt1 address-netmask 120.210.1.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite_mppp
rip add interface to_hqsite_fract1
rip add interface to_hqsite_fullt1
rip start
```


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Internet Service Provider B RS 32000 Configuration

The following configuration applies to the RS 32000 router at Internet Service Provider B.

```
!-------------------------------------------------------------------------
!Configuration for the RS 32000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip start
```


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Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
interface create ip to_ispb1 address-netmask 110.25.30.4/24 port mp.1 up
interface create ip to_ispb2 address-netmask 110.25.31.5/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(13-16)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(17-20)
interface create ip to_ispb1 address-netmask 130.65.20.7/24 port mp.1 up
interface create ip to_ispb2 address-netmask 130.65.21.8/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```


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30.18.6 Scenario 6: Routed Inter-Office Connections with E1 on RS8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. To access the shared data or the Internet, all sites have four E1 lines grouped into a Multilink PPP bundle to connect to the ISP, and so are just one hop away.

The company also has significant inter-office communications. All remote sites frequently communicate with head office, so an E1 line is provided to each remote site. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by an E1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized E3 connection on their proprietary router, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 30-10 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized E1 interfaces are described.

Note The configurations in this example specify timeslots 1-31 for the E1 ports. This excludes the use of timeslot 16. If timeslot 16 is to be used, then **`ts16`** must be included in the relevant commands. For example:

```
port set e1.2.1:1 timeslots 1-31 ts16 wan-encapsulation ppp
```

Hardware Requirements

Router	Hardware Requirements
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 4 E1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 4 E1 WICs.
RS 3000 (rsite4)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 E1 WICs.

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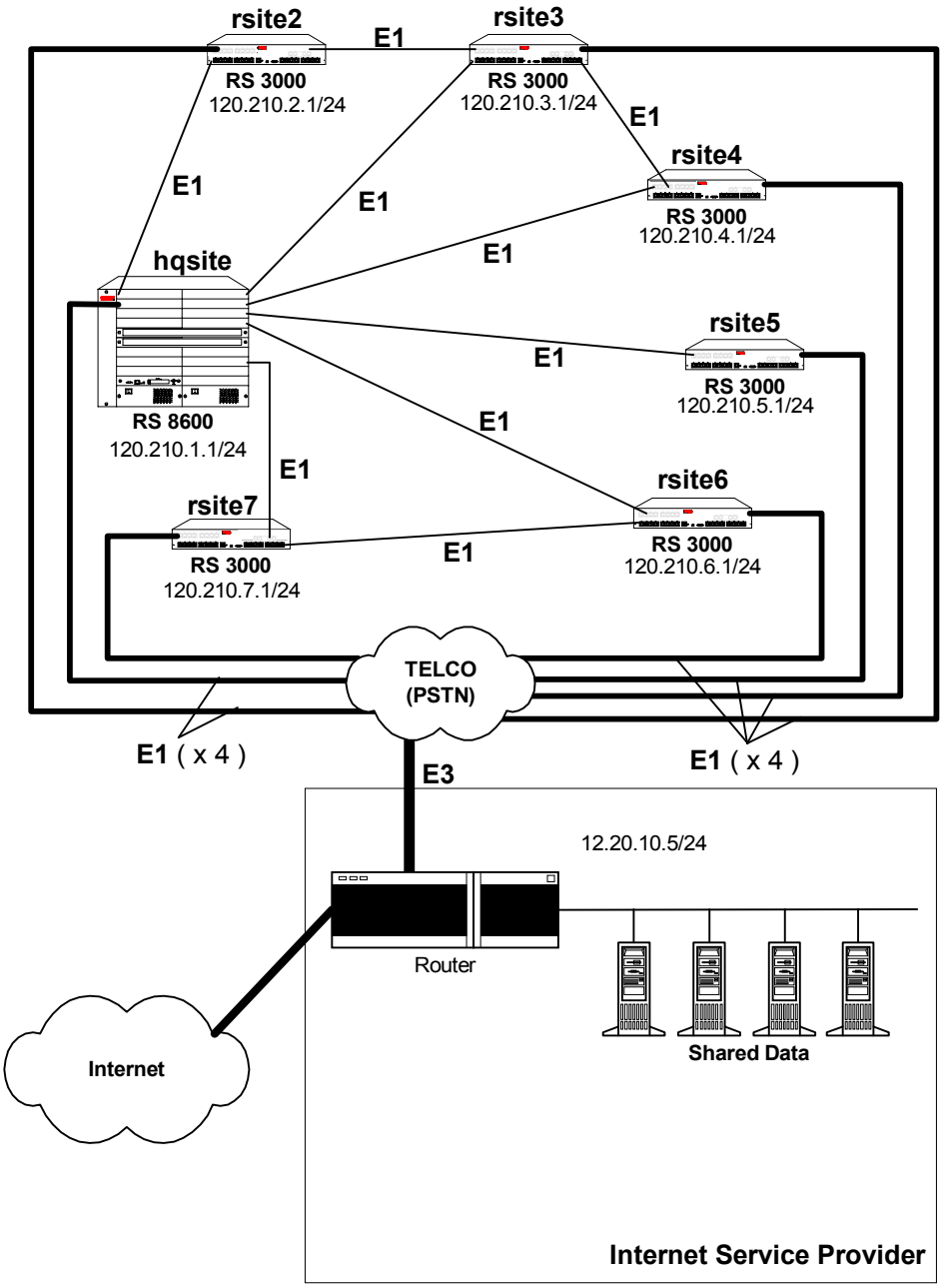

Figure 30-10 Routed Inter-Office Connections with E1 on RS 8x00

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hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.1.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the remote sites:
!-------------------------------------------------------------------------
port set e1.3.(1-4) framing crc4
port set e1.3.(1-4):1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.12.2/24 port e1.3.1 up
interface create ip to_rsite3 address-netmask 120.210.13.3/24 port e1.3.2 up
interface create ip to_rsite4 address-netmask 120.210.14.4/24 port e1.3.3 up
interface create ip to_rsite5 address-netmask 120.210.15.5/24 port e1.3.4 up
port set e1.4.(1-2) framing crc4
port set e1.4.(1-2):1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite6 address-netmask 120.210.16.6/24 port e1.4.1 up
interface create ip to_rsite7 address-netmask 120.210.17.7/24 port e1.4.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the hqsite:
!-------------------------------------------------------------------------
port set e1.3.1 framing crc4
port set e1.3.1:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.12.1/24 port e1.3.1 up
!-------------------------------------------------------------------------
!E1 interface to the rsite3:
!-------------------------------------------------------------------------
port set e1.3.2 framing crc4
port set e1.3.2:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.3/24 port e1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```


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rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the hqsite:
!-------------------------------------------------------------------------
port set e1.3.1 framing crc4
port set e1.3.1:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.13.1/24 port e1.3.1 up
!-------------------------------------------------------------------------
!E1 interface to the rsite2:
!-------------------------------------------------------------------------
port set e1.3.2 framing crc4
port set e1.3.2:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.2/24 port e1.3.2 up
!-------------------------------------------------------------------------
!E1 interface to the rsite3:
!-------------------------------------------------------------------------
port set e1.3.3 framing crc4
port set e1.3.3:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.4/24 port e1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```

30.18.7 Scenario 7: Transatlantic Connection using T1 and E1 on RS 8x00

In this scenario, a T1 link on an RS 8600 is used to connect a company's site in the USA with its site in Europe. The European site has an RS 8000, with an E1 interface. The T1 interface is configured to use the SF framing at a speed of 56Kbps because the local loop does not support B8ZS. Also, the E1 interface assumes that the T1 is delivered on timeslots 1 to 24, including timeslot 16.

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Figure 30-11 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and E1 interfaces on each router are described.

Hardware Requirements

Router	Hardware Requirements
RS 8600 (USA)	1 Multi-Rate WAN module with 1 T1 WIC.
RS 8000 (Europe)	1 Multi-Rate WAN module with 1 E1 WIC.

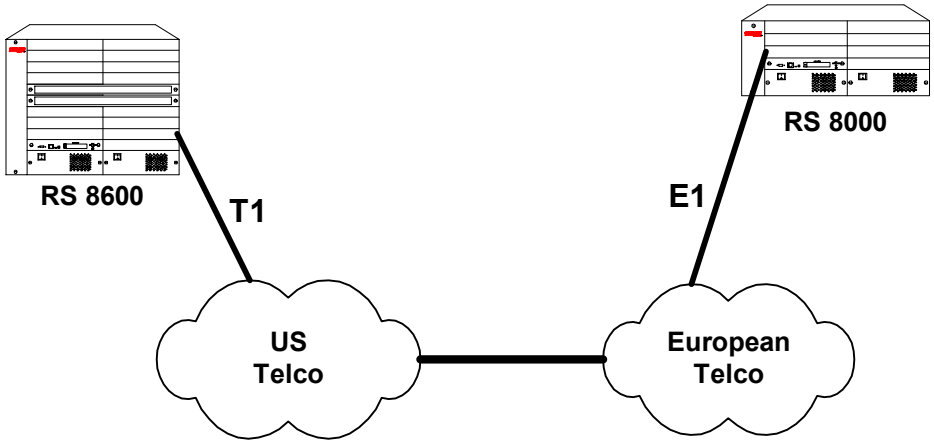

Figure 30-11 Transatlantic Connection Using a T1 and E1 Link

RS 8600 Configuration (USA)

The following configuration applies to the RS 8600 router.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interface
!-------------------------------------------------------------------------
!T1 interface to Europe:
!(speed-56 is used because the local loop does not support B8ZS)
!-------------------------------------------------------------------------
port set t1.2.1 framing sf
port set t1.2.1:1 timeslots 1-24 speed-56 wan-encapsulation ppp

interface create ip to_europe address-netmask 120.210.23.18/24 port t1.2.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_europe
rip start
```


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RS 8000 Configuration (Europe)

The following configuration applies to the RS 8000 router.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 E1 interface
!-------------------------------------------------------------------------
!E1 interface to the USA:
!(assumes T1 is delivered on timeslots 1-24, including timeslot 16)
!-------------------------------------------------------------------------
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-24 ts16 speed-56 wan-encapsulation ppp

interface create ip to_europe address-netmask 120.210.24.18/24 port e1.2.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_usa
rip start
```


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30.18.8 Scenario 8: Configuring Frame Relay over Channelized T1 Interfaces

In this scenario, a Channelized T1 link on an RS 8600 is used to connect a company's headquarters to six remote sites. The headquarters site has an RS 8600, with a Channelized T1 interface. The Channelized T1 interface is configured to use the ESF framing. Each remote site is assigned a consecutive range of four timeslots as shown in Table 30-6. The Frame Relay CIR and Bc for each remote site is also shown. Remote sites, rsite1 and rsite2, have two VCs on the Channelized T1 interface.

Note The timeslot assignments for each site need not be different; they are different in this example for clarity.

Table 30-6 Timeslot and CIR Assignments

Router	Timeslot assignment	CIR	Bc	VC Number	Subnet
rsite1	1-4	64000 64000	128000 128000	106 107	110.110.110.0 110.110.115.0
rsite2	5-8	64000 64000	128000 128000	106 107	110.110.120.0 110.110.115.0
rsite3	9-12	128000	256000	106	110.110.130.0
rsite4	13-16	128000	256000	106	110.110.140.0
rsite5	17-20	128000	256000	106	110.110.150.0
rsite6	21-24	128000	256000	106	110.110.160.0

Figure 30-12 shows the network layout for this scenario. The tables following the figure show the commands used to configure the Channelized T1 interfaces for the routers at the various locations.

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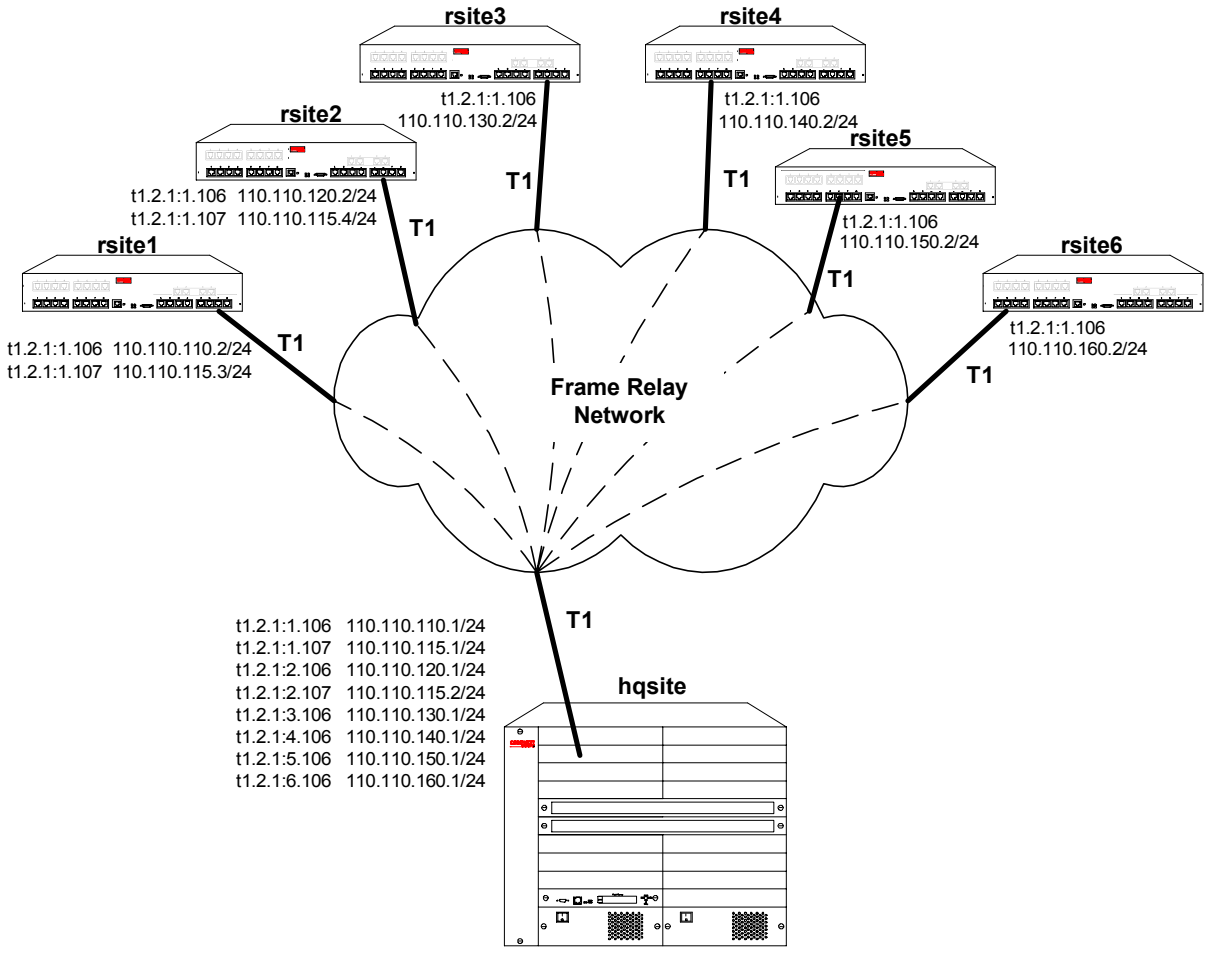

Figure 30-12 Frame Relay over Channelized T1

rsite1 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-4 wan-encapsulation frame-relay
interface create ip rs1_hq_1 address-netmask 110.110.110.2/24 port t1.2.1:1.106 up
interface create ip rs1_hq_2 address-netmask 110.110.115.3/24 port t1.2.1:1.107 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forR1toHQ cir 64000 bc 128000
frame-relay apply service CIR1forR1toHQ ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forR1toHQ cir 64000 bc 128000
frame-relay apply service CIR2forR1toHQ ports t1.2.1:1.107
```


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rsite2 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 5-8 wan-encapsulation frame-relay
interface create ip rs2_hq_1 address-netmask 110.110.120.2/24 port t1.2.1:1.106 up
interface create ip rs2_hq_2 address-netmask 110.110.115.4/24 port t1.2.1:1.107 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forR2toHQ cir 64000 bc 128000
frame-relay apply service CIR1forR2toHQ ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forR2toHQ cir 64000 bc 128000
frame-relay apply service CIR2forR2toHQ ports t1.2.1:1.107
```

rsite3 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 9-12 wan-encapsulation frame-relay
interface create ip rs3_hq address-netmask 110.110.130.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR3toHQ cir 128000 bc 256000
frame-relay apply service CIRforR3toHQ ports t1.2.1:1.106
```

rsite4 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 13-16 wan-encapsulation frame-relay
interface create ip rs4_hq address-netmask 110.110.140.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR4toHQ cir 128000 bc 256000
frame-relay apply service CIRforR4toHQ ports t1.2.1:1.106
```

rsite5 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 17-20 wan-encapsulation frame-relay
interface create ip rs5_hq address-netmask 110.110.150.2/24 port t1.2.1:1 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR5toHQ cir 128000 bc 256000
frame-relay apply service CIRforR5toHQ ports t1.2.1:1.106
```


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rsite6 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 21-24 wan-encapsulation frame-relay
interface create ip rs6_hq address-netmask 110.110.160.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR6toHQ cir 128000 bc 256000
frame-relay apply service CIRforR6toHQ ports t1.2.1:1.106
```

hqsite RS 8600 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set t1.2.1:2 timeslots 5-8 wan-encapsulation frame-relay
port set t1.2.1:3 timeslots 9-12 wan-encapsulation frame-relay
port set t1.2.1:4 timeslots 13-16 wan-encapsulation frame-relay
port set t1.2.1:5 timeslots 17-20 wan-encapsulation frame-relay
port set t1.2.1:6 timeslots 21-24 wan-encapsulation frame-relay
interface create ip rsite1_1 address-netmask 110.110.110.1/24 port t1.4.1:1.106 up
interface create ip rsite1_2 address-netmask 110.110.115.1/24 port t1.4.1:1.107 up
interface create ip rsite2_1 address-netmask 110.110.120.1/24 port t1.4.1:2.106 up
interface create ip rsite2_2 address-netmask 110.110.115.2/24 port t1.4.1:1.107 up
interface create ip rsite3 address-netmask 110.110.130.1/24 port t1.4.1:3.106 up
interface create ip rsite4 address-netmask 110.110.140.1/24 port t1.4.1:4.106 up
interface create ip rsite5 address-netmask 110.110.150.1/24 port t1.4.1:5.106 up
interface create ip rsite6 address-netmask 110.110.160.1/24 port t1.4.1:6.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forHQtoR1 cir 64000 bc 128000
frame-relay apply service CIR1forHQtoR1 ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forHQtoR1 cir 64000 bc 128000
frame-relay apply service CIR2forHQtoR1 ports t1.2.1:1.107
frame-relay create vc port t1.2.1:2.106
frame-relay define service CIR1forHQtoR2 cir 64000 bc 128000
frame-relay apply service CIR1forHQtoR2 ports t1.2.1:2.106
frame-relay create vc port t1.2.1:2.107
frame-relay define service CIR2forHQtoR2 cir 64000 bc 128000
frame-relay apply service CIR2forHQtoR2 ports t1.2.1:2.107
frame-relay create vc port t1.2.1:3.106
frame-relay define service CIRforHQtoR3 cir 128000 bc 256000
frame-relay apply service CIRforHQtoR3 ports t1.2.1:3.106
frame-relay create vc port t1.2.1:4.106
frame-relay define service CIRforHQtoR4 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR4 ports t1.2.1:4.106
frame-relay create vc port t1.2.1:5.106
frame-relay define service CIRforHQtoR5 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR5 ports t1.2.1:5.106
frame-relay create vc port t1.2.1:6.106
frame-relay define service CIRforHQtoR6 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR6 ports t1.2.1:6.106
```


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30.19 SCENARIOS FOR DEPLOYING CLEAR CHANNEL T3 AND E3

This section describes some scenarios for deploying Clear Channel T3.There are two scenarios, which cover the deployment for:

- Routed inter-office connections through an Internet Service Provider (ISP) (see Section 30.19.1)
- Routed Metropolitan Backbone (see Section 30.19.2)

30.19.1 Scenario 1: Routed Inter-Office Connections through and ISP

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8000, and the remote sites each have an RS 3000. All remote sites have four Channelized T1 lines grouped into a Multilink PPP bundle to connect to the RS 8000 at head office. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by a Channelized T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 8000, a LAN that connects to the servers containing the shared data required by the company, and a Clear Channel T3 connection to the Internet.

Figure 30-13 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface.

Hardware Requirements

Router	Hardware Requirements
RS 8000	1 Channelized T3 module. 1 Multi-Rate WAN module with 1 Clear Channel T3 WIC
RS 8000 (hqsite)	1 Channelized T3 module. 6 Multi-Rate WAN modules with 12 Channelized T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite4)	1 Multi-Rate WAN module with 2 Channelized T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.

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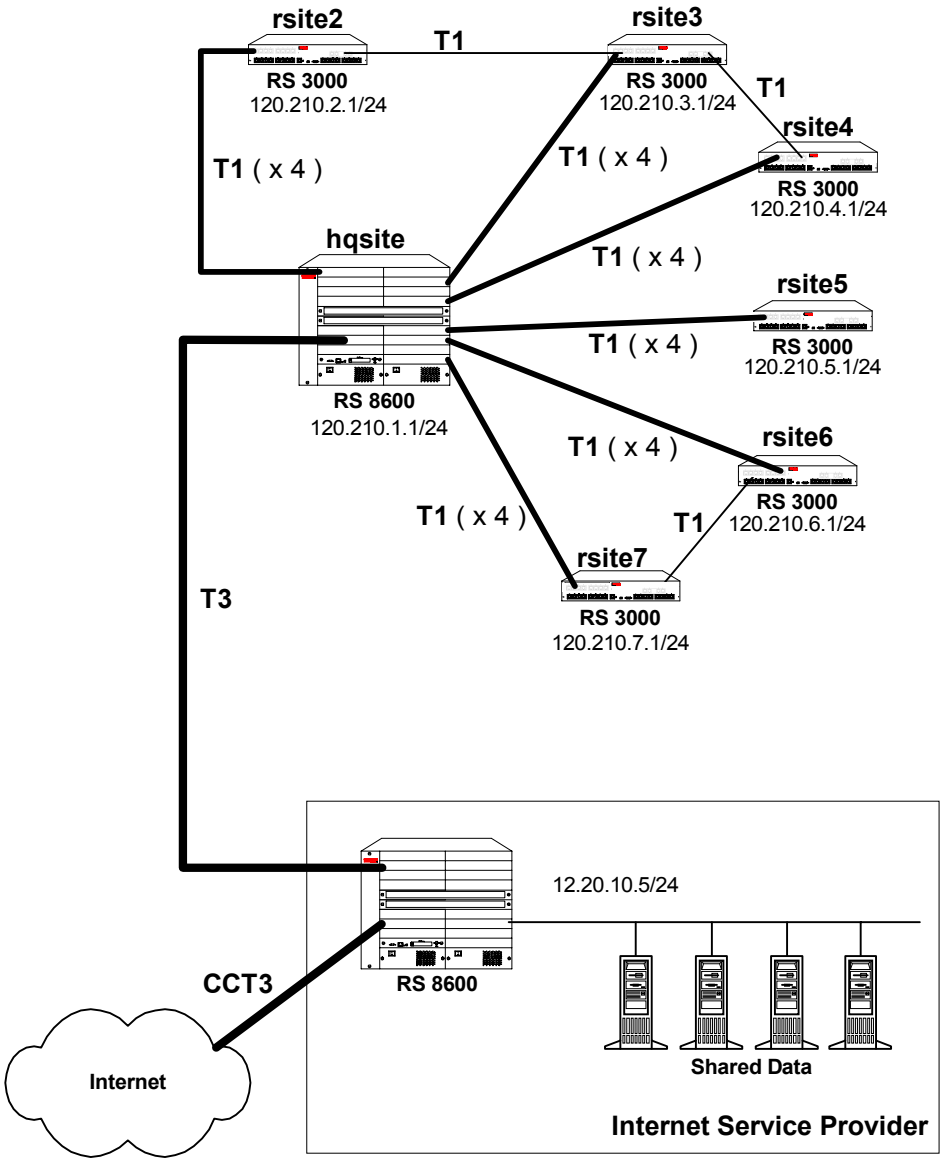

Figure 30-13 Routed Inter-Office Connections through an ISP

KEY:

T3 refers to Channelized T3

CCT3 refers to Clear Channel T3

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ISP RS 8000 Configuration

The following configuration applies to the RS 8000 router at the ISP.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interface to the Internet
!-----------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_internet address-netmask 155.32.2.1/24 port t3.2.1 up
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite2 address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite3 address-netmask 120.210.13.1/24 port mp.3 up
interface create ip to_rsite4 address-netmask 120.210.14.1/24 port mp.4 up
interface create ip to_rsite5 address-netmask 120.210.15.1/24 port mp.5 up
interface create ip to_rsite6 address-netmask 120.210.16.1/24 port mp.6 up
interface create ip to_rsite7 address-netmask 120.210.17.1/24 port mp.7 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip add interface to_internet
rip start
```


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hqsite RS 8000 Configuration

The following configuration applies to the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_isp1 address-netmask 12.20.11.2/24 port mp.1 up
interface create ip to_isp2 address-netmask 12.20.12.2/24 port mp.2 up
interface create ip to_isp3 address-netmask 12.20.13.2/24 port mp.3 up
interface create ip to_isp4 address-netmask 12.20.14.2/24 port mp.4 up
interface create ip to_isp5 address-netmask 12.20.15.2/24 port mp.5 up
interface create ip to_isp6 address-netmask 12.20.16.2/24 port mp.6 up
interface create ip to_isp7 address-netmask 12.20.17.2/24 port mp.7 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp1
rip add interface to_isp2
rip add interface to_isp3
rip add interface to_sip4
rip add interface to_isp5
rip add interface to_isp6
rip add interface to_isp7
rip start
```


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The following configuration applies to the T1 interfaces on the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.5.(1-4) framing esf lbo -7.5db
port set t1.5.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.6.(1-4) framing esf lbo -7.5db
port set t1.6.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.7.(1-4) framing esf lbo -7.5db
port set t1.7.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.8.(1-4) framing esf lbo -7.5db
port set t1.8.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.9.(1-4) framing esf lbo -7.5db
port set t1.9.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.10.(1-4) framing esf lbo -7.5db
port set t1.10.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.9 slot 5
ppp add-to-mlp mp.9 port t1.5.(1-4):1
interface create ip to_rsite2 address-netmask 120.210.2.1/24 port mp.9 up
ppp create-mlp mp.10 slot 6
ppp add-to-mlp mp.10 port t1.6.(1-4):1
interface create ip to_rsite3 address-netmask 120.210.3.1/24 port mp.10 up
ppp create-mlp mp.11 slot 7
ppp add-to-mlp mp.11 port t1.7.(1-4):1
interface create ip to_rsite4 address-netmask 120.210.4.1/24 port mp.11 up
ppp create-mlp mp.12 slot 8
ppp add-to-mlp mp.12 port t1.8.(1-4):1
interface create ip to_rsite5 address-netmask 120.210.5.1/24 port mp.12 up
ppp create-mlp mp.13 slot 9
ppp add-to-mlp mp.13 port t1.9.(1-4):1
interface create ip to_rsite6 address-netmask 120.210.6.1/24 port mp.13 up
ppp create-mlp mp.14 slot 10
ppp add-to-mlp mp.14 port t1.10.(1-4):1
interface create ip to_rsite7 address-netmask 120.210.7.1/24 port mp.14 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```


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rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```


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rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite4:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.3/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```


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30.19.2 Scenario 2: Routed Metropolitan Backbone

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 8000s connected by Clear Channel T3 (CCT3) links.

An MSP provides a Channelized T3 (CT3) service using an RS 8000. A company has two sites that connect to this service:

- The head office (hqsite) connects using a Channelized T3 line from an RS 8000.
- The remote site, rsite, connects to the RS 8000 at head office using four Channelized T1 lines bundled with Multilink PPP, a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the RS 8000.

Internet Service Provider A uses a Clear Channel T3 link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using Channelized T3 lines from an RS 8000.

Figure 30-14 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations.

Hardware Requirements

Router	Hardware Requirements
RS 8000 (MSP)	1 Channelized T3 module (2 ports). 1 Multi-Rate WAN module with 2 Clear Channel T3 WICs
RS 8000 (hqsite)	1 Channelized T3 module (with 2 T3 ports). 2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 8000 (ISP A)	2 Multi-Rate WAN modules with 3 Clear Channel T3 WICs
RS 8000 (ISP B)	1 ChannelizedT3 module (2 ports). 1 Multi-Rate WAN module with 2 Clear Channel T3 WICs
RS 8000 (CP)	1 ChannelizedT3 module (with 2 T3 ports).
RS 8000 (ASP)	1 ChannelizedT3 module (with 2 T3 ports).

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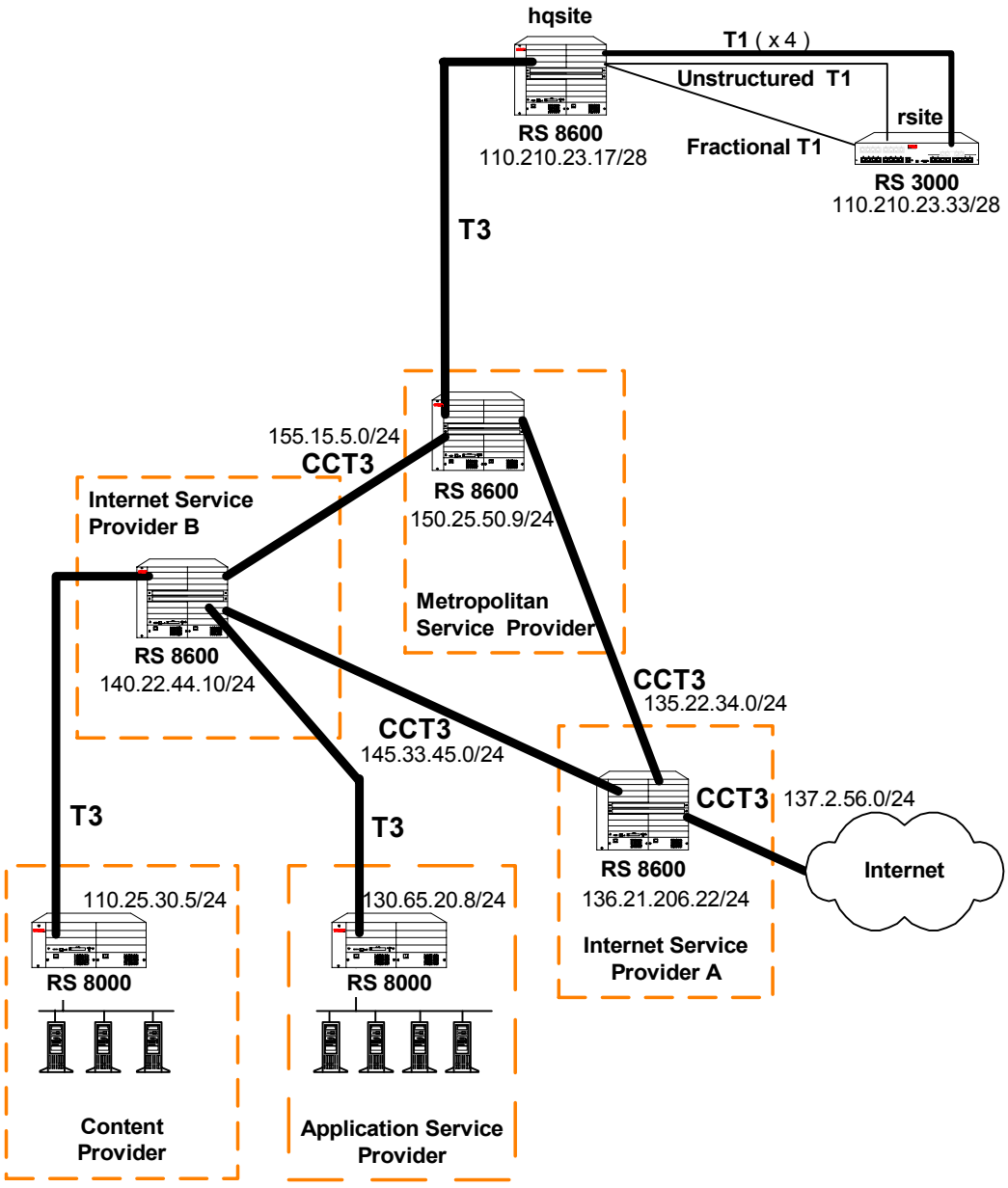

Figure 30-14 Routed Metropolitan Backbone

KEY:

T3 refers to Channelized T3

CCT3 refers to Clear Channel T3

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Metropolitan Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_ispa address-netmask 135.22.34.2/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_ispb address-netmask 155.15.5.2/24 port t3.2.2 up
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite_ft1 address-netmask 120.210.13.1/24 port t3.4.1:13 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip add interface to_ispa
rip add interface to_ispb
rip start
```


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hqsite RS 8000 Configuration

The following configuration applies to the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure a multilink PPP bundle containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)

interface create ip to_msp address-netmask 120.210.11.2/24 port mp.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp
rip start
```


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The following configuration applies to the T1 interfaces on the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the rsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_rsite_mppp address-netmask 120.210.4.1/24 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite_fullt1 address-netmask 120.210.1.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.2:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.2:3 timeslots 19 wan-encapsulation ppp
port set t1.3.2:4 timeslots 20 wan-encapsulation ppp
port set t1.3.2:5 timeslots 21 wan-encapsulation ppp
port set t1.3.2:6 timeslots 22 wan-encapsulation ppp
port set t1.3.2:7 timeslots 23 wan-encapsulation ppp
port set t1.3.2:8 timeslots 24 wan-encapsulation ppp
interface create ip to_rsite_fract1 address-netmask 120.210.24.1/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite_mppp
rip add interface to_rsite_fullt1
rip add interface to_rsite_fract1
rip start
```


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rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite_mppp address-netmask 120.210.4.2/24 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_hqsite_fract1 address-netmask 120.210.24.2/24 port t1.3.1
up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite_fullt1 address-netmask 120.210.1.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite_mppp
rip add interface to_hqsite_fract1
rip add interface to_hqsite_fullt1
rip start
```


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Internet Service Provider A RS 8000 Configuration

The following configuration applies to the RS 8000 router at Internet Service Provider A.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_internet address-netmask 137.2.56.1/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_msp address-netmask 135.22.34.1/24 port t3.2.2 up
port set t3.3.1 cablelength 200 wan-encapsulation ppp
interface create ip to_ispb address-netmask 145.33.45.1/24 port t3.3.1 up
!-------------------------------------------------------------------------
!Configuration for the RS 8000 channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!Configure the T1 lines on the T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip add interface to_msp
rip add interface to_ispb
rip add interface to_internet
rip start
```


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Internet Service Provider B RS 8000 Configuration

The following configuration applies to the RS 8000 router at Internet Service Provider B.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_msp address-netmask 155.15.5.1/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_ispa address-netmask 145.33.45.2/24 port t3.2.2 up
!-------------------------------------------------------------------------
!Configuration for the RS 8000 channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!Configure the T1 lines on the T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip add interface to_msp
rip add interface to_ispa
rip start
```


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Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
interface create ip to_ispb1 address-netmask 110.25.30.4/24 port mp.1 up
interface create ip to_ispb2 address-netmask 110.25.31.5/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(13-16)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(17-20)
interface create ip to_ispb1 address-netmask 130.65.20.7/24 port mp.1 up
interface create ip to_ispb2 address-netmask 130.65.21.8/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```


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31 SERVICE CONFIGURATION

The **service** facility is used to configure rate limiting. It has been designed to reduce the amount of work it takes to configure a large number of things that require the same configuration. The **service** facility reduces the complexity of configuring rate limiting on the RS.

This facility can be applied across a variety of network configurations such as an individual flow or an aggregate of flows. Additionally, it can be used to configure committed access rates and burst rates. See 31.2.4 *"Burst-Safe Rate Limiting Service"* for more information about committed access rates and burst rates.

The **service** facility is applied using a feature called Multi Field Classifier (MF Classifier). An MF Classifier is a mechanism for classifying traffic based on the fields of an IP packet. The MF Classifier retrieves the TCP/UDP source socket number from a packet and uses this information when applying the service. See 31.3.2 *"Applying Services Using the MF-Classifier Command"* for information about MF Classifiers.

The advantages of the **service** commands are:

- Less commands are used when configuring a rate limit.
- One service can be applied to one, many, or an unlimited number of interfaces and/or ports using the MF Classifier.
- ACLs do not need be defined when using **service** rate limiting.

To illustrate the advantages two examples follow. In the first, an ACL named *acl1* is created. Then an aggregate rate limit of 2 million packets that uses *acl1* is created. The name of the rate limit is *test1*. Finally the rate limit is applied to interface *test2*. In the second example, the service *test1* is created with a flow-aggregate rate limit of 2 million packets. Then it is applied to interface *test2*. The examples show that a service is created using less commands and no ACLs. The section 31.6.1 *"Applying a Service to Multiple Servers"* shows how one service is applied to one, many, or an unlimited number of interfaces and/or ports.

Here is the example of the **acl** and **rate-limit** commands required to configure rate limiting:

```
! Create a rate limit
rs(config)# acl acl1 permit ip 10.50.1.0/24 any
rs(config)# rate-limit test1 aggregate acl acl1 rate 2000000 drop-packets
rs(config)# rate-limit test1 apply interface test2
```

Here is the example of the **service** commands required to configure rate limiting:

```
! Create a service with an MF Classifier
rs(config)# service test1l create rate-limit flow-aggregate rate 2000000
exceed-action drop-packets distribute-among 4
rs(config)# service test1 apply rate-limit mf-classifier interface test2
source-addr-mask 10.9.1.3/24
```


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Once created, **acl1** becomes bound to the policy and the policy becomes bound to the IP address specified in the policy. Because it is bound, it can not be used at another IP address. A new policy has to be created with the same rate limits. That requires more commands. With the **service** facility, the policy need only be configured once for any number of addresses. Additionally, an ACL does not have to be created. As seen in the second example, the **apply** command handles the filtering by including a source address using **source-addr-mask**.

Note Currently **service** supports rate limiting and ACLs.

31.1 SERVICE FACILITY RATE LIMITING TYPES

There are four types of rate-limiting used in the **service** facility:

Aggregate rate limiting – The aggregate rate limiting service is used for aggregate flows and executed exclusively in the hardware.

Note Some line cards do not support aggregate rate limiting. Do not choose aggregate rate limiting if a line card does not support this type of limiting.

Flow-aggregate rate limiting – The flow-aggregate rate limiting service is used for aggregate flows and executed in a combination of hardware and software.

Per-flow rate limiting – Use the per-flow rate limiting service to limit individual flows.

Burst-safe rate limiting – Use the burst-safe rate limiting service if Committed Access Rates (CARs) (guaranteed transmissions) or burst rates (non-guaranteed transmissions) are required to limit traffic.

Note Burst-safe is supported on line cards that support aggregate rate limiting.

Note Port rate limiting must be disabled on a port to use burst-safe rate limiting on that port.

A *traffic profile* is used to define the traffic characteristics before an upper limit is assigned. The traffic profile is created using an ACL, which can utilize any combination of the parameters supported in IP ACL. A rate limiting policy can then be defined by using the ACL and traffic rate limitations. You define the action to be taken on the traffic that exceeds the upper limit. For example, dropping packets. Except for port rate limiting, the rate limiting policy is then applied to a logical IP interface.

Rate limiting policies work only in one direction. That is, only the traffic coming into the interface to which a policy is applied will be subject to rate limiting (except for output port rate limiting policies, which are applied to egress ports). If both incoming and outgoing traffic to a network or subnet needs to be rate limited, then you should create separate policies to be applied to each interface.

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31.2 CREATING A SERVICE

31.2.1 Aggregate Rate Limiting Service

An aggregate rate limiting policy can not be applied to an interface that spans ports on more than one channel. For example, an aggregate rate limiting policy can not be applied to the interface *ip2* if it interfaces with a VLAN that consists of ports et.1.(1-4) and et.2.(1-4). The aggregate rate limiting mode will need to be enabled on the line card to be able to configure aggregate rate limiting.

To create an aggregate rate limiting service, use the following command:

Create an aggregate rate limiting service.	**service** <*name*> **create rate-limit aggregate rate** <*rate*> [**no-action** | **drop-packets** | **lower-priority** | **lower-priority-except-control** | **tos-precedence-rewrite** <*num*> | **tos-precedence-rewrite-lower-priority** <*num*> | **tos-rewrite** <*num*> | **tos-rewrite-lower-priority** <*num*>] | **time-select** <*num*>]

Here is an example:

```
! Create an aggregate service, limiting an aggregate flow to 2 million bps and drops packets if the rate is exceeded
rs(config)# service mktaggregate create rate-limit aggregate rate 2000000 drop-packets
```

Hardware Credit Buckets

Aggregate rate limiting uses a hardware *credit bucket* scheme to perform rate limiting. It is essentially allocated space in memory and is built into all rate-enabled line cards. Hardware credit bucket works by limiting how much traffic is allowed to pass through a physical port. As traffic passes through the port, credits are deducted from the credit bucket.

Service providers control the amount of credit in the bucket, depending on the amount of bandwidth allocated; the more bandwidth, the more credit for that type of traffic. When traffic passes through a physical port or matches a predefined profile while passing through an interface, credit is deducted from the bucket. When all the credits have been used and traffic has exhausted all allocated bandwidth, action is taken on the excess traffic. Packets are either dropped, dropped to a lower priority, or ToS precedence is rewritten.

The credit bucket scheme consists of two major components, credit count and replenish rate:

Credit count – The amount of credits in each bucket. Credit count defines how much credit is available for a physical port or a specific type of traffic. It determines when traffic is considered to be excessive, based on the availability of credit.

Replenish rate – Determines when or how often credit buckets are refilled. If the replenish rate is too low, there will not be a sufficient amount of credits when traffic arrives. If the replenish rate is too high, it will reduce the effectiveness of the rate-limiting policy.

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Both the credit count and the replenish rate are calculated by the RS according to the rate-limiting profile defined in the configuration. The RS uses a special algorithm to determine the best credit count and replenish rate to achieve optimum bandwidth control.

Figure 31-1 shows the operation of the hardware credit bucket.

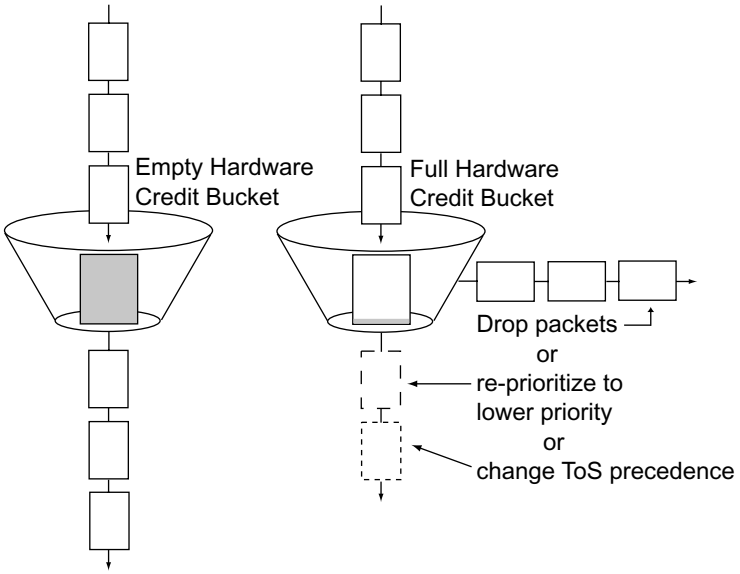

Figure 31-1 Hardware credit buckets

All credit validation is performed locally in the line card. The control module only becomes involved when a new entry needs to be created in the hardware. It programs the entry in the ASICs on the line card, then subsequent packets are handled locally.

31.2.2 Flow-Aggregate Rate Limiting Service

Flow-aggregate rate limiting can be used on line cards that are not enabled for aggregate rate limiting. It can also be used on cards that do not support aggregate rate limiting. If aggregate rate limiting is enabled on a particular line card, per-flow rate limiting policies can not be applied to ports on that line card.

To create a flow-aggregate rate limiting service, use the following command:

Create a flow-aggregate rate limiting service.	**service** <*name*> **create rate-limit flow-aggregate rate** <*rate*> [**exceed-action** <**drop-packets** | **set-priority-low** | **set-priority-medium** | **set-priority-high**> **min-bandwidth** <*minbw*> **distribute-among** <*distribute*> | **time-select** <*num*>]

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Here is an example:

```
! Create a flow-aggregate service, limiting an aggregate flow to 10 million bps, drops packets if the rate is exceeded
! and distributed across 10 flows
rs(config)# service testaggregate create rate-limit flow-aggregate rate 10000000
exceed-action drop-packets distribute-among 10
```

31.2.3 Per-Flow Rate Limiting Service

Per-flow rate limiting is enabled on the RS by default. If aggregate rate limiting is enabled on a particular line card, per-flow rate limiting policies can not be applied to ports on that line card.

To create a per-flow rate limiting service, use the following command:

Create a per-flow rate limiting service.	**service** <*name*> **create rate-limit per-flow rate** <*rate*> [**exceed-action** <**drop-packets** | **set-priority-low** | **set-priority-medium** | **set-priority-high**> | **time-select** <*num*>]

Here is an example:

```
! Create a per flow service, limiting one flow to 1 million bps and drops packets if the rate is exceeded
rs(config)# service user1flow create rate-limit per-flow rate 1000000 exceed-action
drop-packets
```


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31.2.4 Burst-Safe Rate Limiting Service

This command creates a burst-safe type rate limiting. Burst-safe allows an administrator to configure committed access rates (CAR) and burst-safe rates for any aggregate of flows. The CAR rate is the rate that is always guaranteed. The burst-safe rate is the *best effort* rate. This is the rate where some traffic may not get through. It is added bandwidth in part for bursty periods. See the note in 31.1 *"Service Facility Rate Limiting Types"* for line card support for burst-safe.

To create a burst-safe rate limiting service, use the following command:

Create a burst-safe rate limiting service.	**service** <*name*> **create rate-limit burst-safe car-rate** <*rate*> [**car-no-action** | **car-drop-packets** | **car-lower-priority** | **car-lower-priority-except-control** | **car-tos-precedence-rewrite** <*num*> | **car-tos-precedence-rewrite-lower-priority** <*num*> | **car-tos-rewrite** <*num*> | **car-tos-rewrite-lower-priority** <*num*>] **burst-rate** <*rate*> [**burst-no-action** | **burst-drop-packets** | **burst-lower-priority** | **burst-lower-priority-except-control** | **burst-tos-precedence-rewrite** <*num*> | **burst-tos-precedence-rewrite-lower-priority** <*num*> | **burst-tos-rewrite** <*num*> | **burst-tos-rewrite-lower-priority** <*num*>] | [**time-select** <*num*>]

Here is an example:

```
! Create a service command profile that allows traffic to burst up to 6 million bps
rs(config)# service sqaservice1 create rate-limit burst-safe car-rate 5000000
burst-rate 1000000 car-tos-rewrite 4
```

31.3 APPLYING A SERVICE

31.3.1 Applying Services With ACLs

The **service apply rate-limit acl** command is used to apply services using ACLs to interfaces or ports. This command is for administrators who prefer to use ACLs rather than MF Classifiers. See 31.3.2 *"Applying Services Using the MF-Classifier Command"* for more information about MF Classifiers.

To apply services using ACLs, use the following commands:

Apply a service that uses ACLs to an interface or a port.	**service** <*name*> **apply rate-limit acl** <*aclname*> **interface** <*intfname*> **service** <*name*> **apply rate-limit acl** <*aclname*> **port** <*port*>

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Here are two examples:

```
! Apply a service to an interface
rs(config)# service userflow1 apply rate-limit acl useracl1 interface userinterface1
```

```
! Apply a service to a port
rs(config)# service mktaggregate apply rate-limit acl mktacl port et.3.3
```

31.3.2 Applying Services Using the MF-Classifier Command

The **service apply rate-limit mf-classifier** command is used to apply services to interfaces or ports using MF Classifiers.

To apply services with MF Classifiers, use the following commands:

Apply a service using an MF Classifier to an interface or port.	**service** <*name*> **apply rate-limit mf-classifier interface** <*name* | **all**> | **port** <*name*> [**source-addr-mask** <*srcadd*> **destination-addr-mask** <*dstadd*> **tos** <*num*> **tos-mask** <*tosmask*> | <**source-port** | **destination-port** <*port type*> <**dns** | **finger** | **ftp-cmd** | **ftp-data** | **http** | **https** | **imap3** | **imap4** | **lpr** | **nfs** | **nntp** | **ntp** | **pop3** | **portmapper** | **rexec** | **rlogin** | **rshell** | **snmp** | **smtp** | **telnet** | **tftp** | **x11**>>]

Here is an example:

```
! Apply the service aggregate1 to an interface
rs(config)# service aggregate1 apply rate-limit mf-classifier interface interface1
source-addr-mask 10.10.10.80 source-port telnet tos 2
```


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31.4 SHOWING A SERVICE

31.4.1 Aggregate, Flow-Aggregate, Per-Flow, and Burst-Safe Show Commands

To show these services, use the following commands:

Display an aggregate, flow-aggregate, per- flow or burst-safe service.	**service show rate-limit aggregate** <*name* | **all**> [**show-applied**] **service show rate-limit flow-aggregate** <*name* | **all**> [**show-applied**] **service show rate-limit per-flow** <*name* | **all**> [**show-applied**] **service show rate-limit burst-safe** <*name* | **all**> [**show-applied**]

Here is an example:

```
! Display an aggregate service
rs# service show rate-limit aggregate testservice2
--------------------------------------------------------------------------------
Service Name: testservice2                    Service Type : Aggregate Rate Limit
Rate        : 600000000 bps                   Exceed Action: Drop Packets
--------------------------------------------------------------------------------
```

The fields are:

Service Name – Name of the service displayed.

Rate – Displays the rate limiting rate.

Service Type – Displays the type of service.

Exceed Action – Displays the action taken when the rate is exceeded.

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31.4.2 Show All Command

To show all services, use the following command:

Display all services. **service show rate-limit all** [**show-applied**]

Here is an example:

```
! Display all services using the show-applied parameter to show which service is applied to which interface
rs# service show rate-limit all show-applied
--------------------------------------------------------------------------------
Service Name : stoptraffic1         Service Type  :  Flow Aggregate Rate Limit
Rate         : 5000000 bps          Exceed Action :  Drop Packets

Service stoptraffic1 is applied on interface site1 with following
traffic classification
Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK      Prot
--------------     -------------      --------- --------- --- ------------- ----
1.2.3.4/24         anywhere           80        any       any None          IP
--------------------------------------------------------------------------------
Service Name : stoptraffic2         Service Type:  Aggregate Rate Limit
Rate         : 6000000 bps          Exceed Action  :  Lower Priority

Service stoptraffic2 is not applied anywhere
--------------------------------------------------------------------------------
Service Name : stoptraffic3         Service Type:  Aggregate Rate Limit
Rate         : 4000000 bps          Exceed Action  :  Drop Packets

Service stoptraffic3 is not applied anywhere
--------------------------------------------------------------------------------
```

The fields are:

Service Name – Name of the service.

Service Type – Type of service applied.

Rate – Rate limit applied by the service.

Exceed Action – The action taken when the rate limit is exceeded.

Source IP/Mask – The source IP address and mask of the flow the service is applied to.

Dest. IP/Mask – The destination IP address and mask of the flow the service is applied to.

SrcPort – The source port of the flow the service is applied to.

DstPort – The destination port of the flow the service is applied to.

TOS – Type of service.

TOS Mask – Type of service mask.

Prot – Type of protocol declared with the service. IP is the default.

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31.5 PORT-LEVEL RATE LIMITING

Note Port-level rate limiting is not yet supported by Service.

Use a port-level rate limiting policy if incoming or outgoing traffic on a particular port needs to be rate limited. Unlike other types of rate limiting policies, do not specify an ACL when defining this type of policy. Port-level rate limiting policies do not need to be applied to an interface and they take effect when they are created.

To configure port-level rate limiting policies for input ports, enable the aggregate rate limiting mode on the line card Do not enable the aggregate rate limiting mode to configure a policy to rate limit outgoing traffic. Configure port-level rate limiting policies on output ports in either the per-flow or aggregate rate limiting modes.

Note For output port policies, the only action to specify if traffic exceeds the specified rate is to drop packets.

When using output port-level policies, all types of outgoing traffic will be rate limited, including control traffic. To prevent the rate limiting of control traffic, use the **`rate-limit port-level slot ignore-control-priority`** command.

31.6 SERVICE CONFIGURATION EXAMPLES

31.6.1 Applying a Service to Multiple Servers

The configuration example in Figure 31-2 shows how easily a network can be configured for aggregate rate limiting using a **`service`** *aggregate1*. S1 through S4 can be rate limited using one service applied to *QAInterface1*.

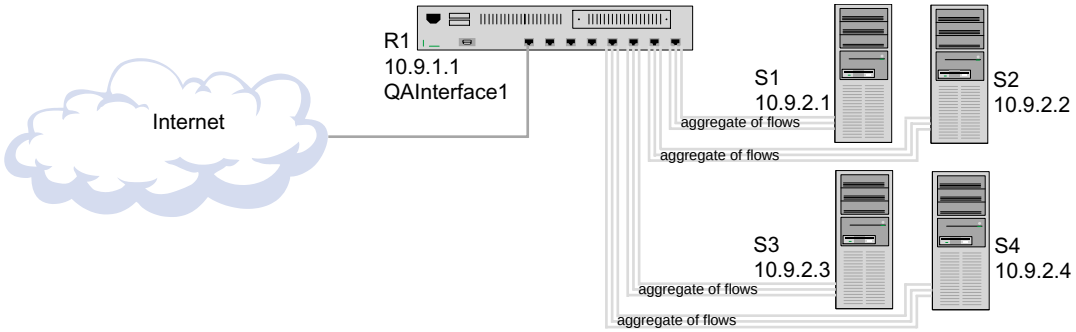

Figure 31-2 Configuration Example: Applying a Service to Multiple Servers

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The configuration shown in Figure 31-2 is created with the following commands:

```
! Enable aggregate rate limiting
rs(config)# system enable aggregate-rate-limiting
! Create the service
rs(config)# service aggregate1 create rate-limit aggregate rate 5000000
drop-packets
! Apply the service to S1, S2, S3 and S4
rs(config)# service aggregate1 apply rate-limit mf-classifier interface
qainterface1 source-addr-mask 10.9.2.1/24
rs(config)# service aggregate1 apply rate-limit mf-classifier interface
qainterface1 source-addr-mask 10.9.2.2/24
rs(config)# service aggregate1 apply rate-limit mf-classifier interface
qainterface1 source-addr-mask 10.9.2.3/24
rs(config)# service aggregate1 apply rate-limit mf-classifier interface
qainterface1 source-addr-mask 10.9.2.4/24
```

31.6.2 Applying Burst-Safe Rate Limiting

The MAN in Figure 31-3 is equipped with RS routers. Because it is equipped with RS routers it can provide *value-added* services to customers lawoffices.com, and corporationone.com and corporationtwo.com. The service is burst-safe rate limiting. This provides added bandwidth for use during bursy traffic periods. The configuration requirements of lawoffices.com are:

- Set the traffic prioritization to high
- Set the CAR to one million bps
- Set the burst-safe rate to one hundred thousand bps
- Set the CAR exceed to priority dropped to medium
- Set the burst-safe rate exceed to packets are dropped

The configuration requirements of corporationone.com and corporationtwo.com are:

- Set the traffic prioritization to medium
- Set the CAR to nine million bps
- Set the burst-safe rate to one million bps
- Set the CAR exceed to priority dropped to low
- Set the burst-safe rate exceed to packets are dropped

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Following is the configuration:

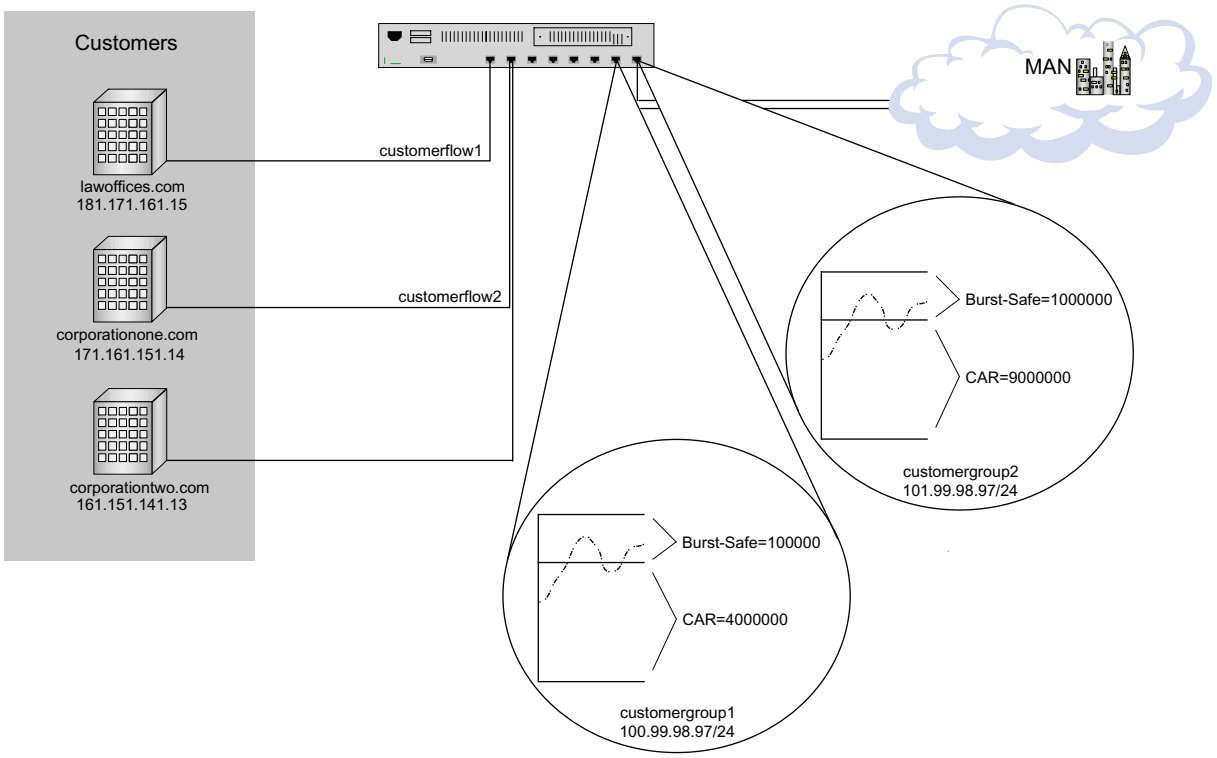

Figure 31-3 Burst-Safe Configuration

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The configuration shown in Figure 31-2 is created with the following commands:

```
! Create the burst-safe service for customerflow1
rs(config)# service customergroup1 create rate-limit burst-safe car-rate 1000000
car-lower-priority burst-rate 100000 burst-drop-packets
! Set the traffic priority
rs(config)# qos set ip customerflow1 high 181.171.161.15/24 100.99.98.97
! Apply the burst-safe service
rs(config)# service customergroup1 apply rate-limit mf-classifier interface
customergroup1 source-addr-mask 181.171.161.15/24
! Create the burst-safe service for customerflow2
rs(config)# service customergroup2 create rate-limit burst-safe car-rate 9000000
car-lower-priority burst-rate 1000000 burst-drop-packets
! Set the traffic priority
rs(config)# qos set ip customerflow2 medium 171.161.151.14/24 101.99.98.97
rs(config)# qos set ip customerflow2 medium 161.151.141.13/24 101.99.98.97
! Apply the burst-safe service
rs(config)# service customergroup2 apply rate-limit mf-classifier interface
customergroup2 source-addr-mask 171.161.151.14/24
rs(config)# service customergroup2 apply rate-limit mf-classifier interface
customergroup2 source-addr-mask 161.151.141.13/24
```

31.7 RATE LIMITING CONFIGURATION EXAMPLES

Per-Flow Rate Limiting

The following is an example of configuring per-flow rate limiting.

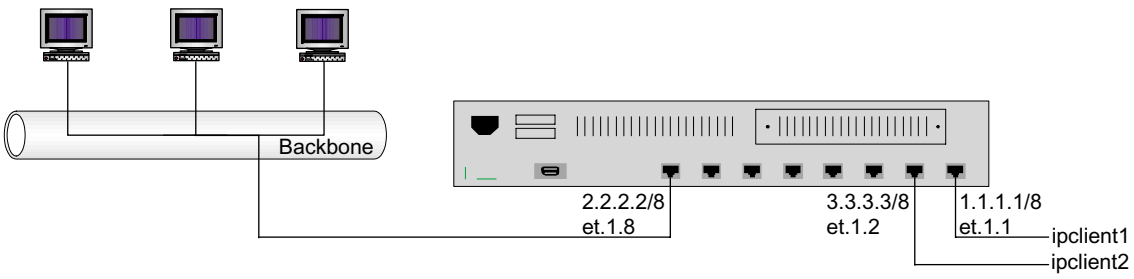

Figure 31-4 Per-flow rate limiting

Traffic from two interfaces, *ipclient1* with IP address 1.2.2.2 and *ipclient2* with IP address 3.1.1.1, is restricted to 10 Mbps for each flow with the following configuration:

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```
vlan create client1 ip
vlan create client2 ip
vlan create backbone ip
vlan add ports et.1.1 to client1
vlan add ports et.1.2 to client2
vlan add ports et.1.8 to backbone
interface create ip ipclient1 vlan client1 address-netmask 1.1.1.1/8
interface create ip ipclient2 vlan client2 address-netmask 3.3.3.3/8
interface create ip backbone vlan backbone address-netmask 2.2.2.2/8
acl 100 permit ip 1.2.2.2
acl 200 permit ip 3.1.1.1
rate-limit client1 input acl 100 rate 10000000 exceed-action drop-packets
rate-limit client2 input acl 200 rate 10000000 exceed-action drop-packets
rate-limit client1 apply interface ipclient1
rate-limit client2 apply interface ipclient2
```

Flow-Aggregate Rate Limiting

The following is an example of configuring flow-aggregate rate limiting.

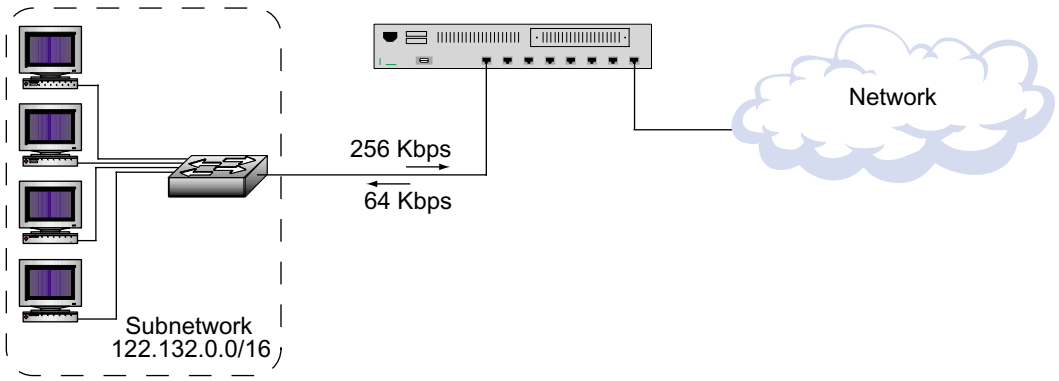

Figure 31-5 Flow-aggregate rate limiting

In the example above, traffic from the subnetwork 122.132.0.0/16 to the Internet will be rate limited to 256 Kbps while traffic to the subnetwork will be rate limited to 64 Kbps.

```
acl cust1 permit ip any 122.132.0.0/16
acl cust1 permit ip 122.132.0.0/16 any
rate-limit cust1 flow-aggregate acl cust1 rate 256000 exceed-action drop-packets
min-bandwidth 4000
rate-limit apply cust1 interface tonet
rate-limit cust1 flow-aggregate acl cust1 rate 64000 exceed-action drop-packets
min-bandwidth 2000
rate-limit apply cust1 interface in1
```


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